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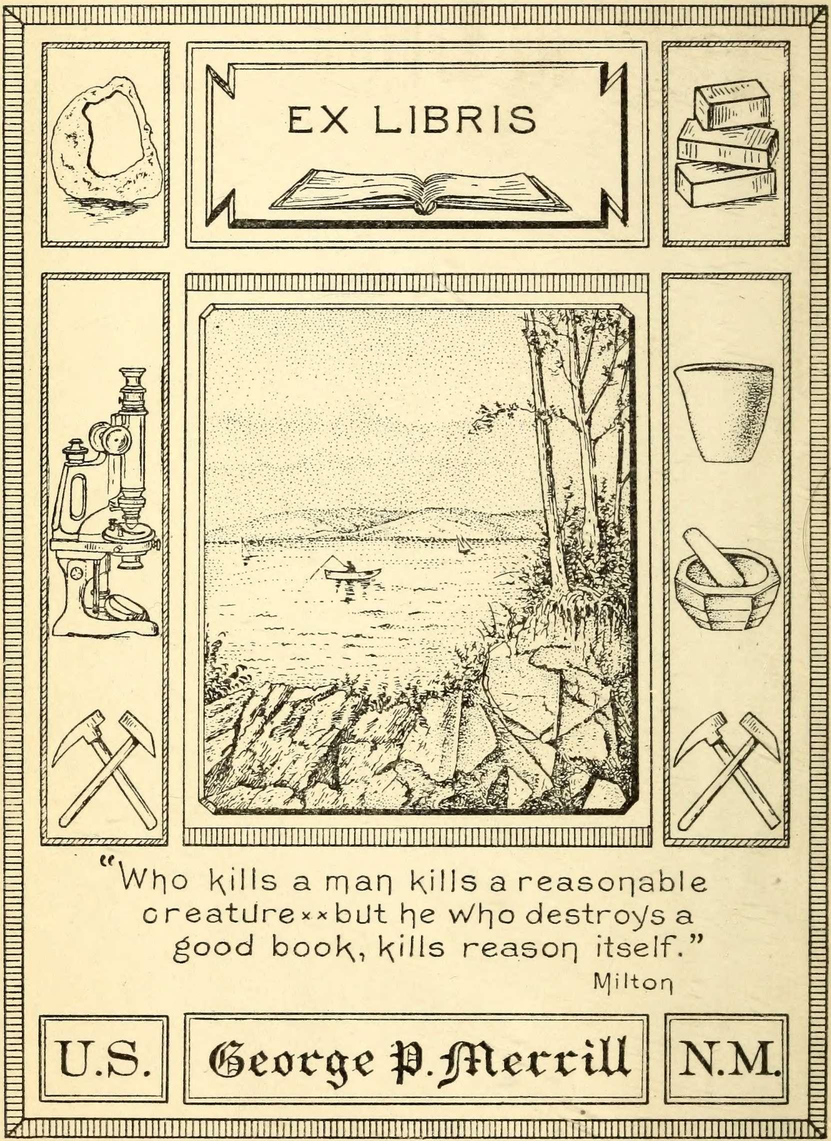

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"Who kills a man kills a reasonable creature ×× but he who destroys a good book, kills reason itself."

Milton

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OUTLINES

OF

GEOLOGY,

Prepared for the use of the

JUNIOR CLASS

OF

COLUMBIA COLLEGE:

BY

JAMES RENWICK, LL.D.,

PROFESSOR OF NATURAL EXPERIMENTAL PHILOSOPHY AND CHEMISTRY.

Wm Pinkney Stewart

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OUTLINES

OF

GEOLOGY.

INTRODUCTION.

1. Geology is that branch of Physical Science which treats of the constitution of the earth we inhabit.

2. Geology has for its objects:

(*a*) To inquire into the form and external characters of our globe;

(*b*) To examine the nature and relative position of the materials which compose its external crust;

(*c*) To investigate, as far as may be in our power, the manner and order in which these materials have assumed their present position.

3. Geology is therefore divided into three distinct departments:

1. Physical Geography;
2. Geognosy;
3. Geogeny.

I. PHYSICAL GEOGRAPHY.

I.

OF THE FIGURE AND DENSITY OF THE EARTH.

4. The earth is a planet of the solar system, having a globular figure, which differs from a perfect sphere in being irregular at its surface, and flattened at its poles. Abstracting from these irregularities, which bear but a small proportion to its lineal dimensions, the figure is that of a spheroid of revolution. The amount of the flattening at the poles may be determined in several ways:

(1.) By the actual measure of portions of the meridians;

(2.) By the variation in the apparent intensity of gravity at the surface, which is ascertained by experiments with the pendulum;

(3.) By astronomic phenomena, which are affected by the figure of the earth.

By these methods the oblateness of the earth is found to be not far from $\frac{1}{300}$; that is to say, the relation of the polar axis to the equatorial diameters is about $\frac{299}{300}$.

We learn from mechanical philosophy, that the figure of an oblate spheroid is that which would be assumed by a fluid mass whose particles are mutually attractive of each other, and which revolves upon an axis; and although we find the external crust of the earth to be at present in a solid form, we know that the figure has exactly that oblateness which is consistent with the state of fluidity. We learn this from the fact, that the cavities in the solid crust are filled with a mass of fluid, (the ocean,) and that this is distributed with tolerable uniformity throughout the whole surface, and is found in every varying latitude. Now, were the earth more oblate than is consistent with the equilibrium of a fluid mass revolving upon an axis, the ocean would have accumulated at the poles; and were it less oblate than would satisfy that condition, the waters would form a fluid zone on each side of the equator.

6. We become acquainted with the density of the earth by comparing its attraction with the mutual attraction of bodies near its surface. In this way it has been ascertained that the mean density of the earth does not differ much from five times that of water. Now, as a very large portion of the surface is actually covered with water, and as the greater part of the remaining surface is composed of earthy matter, whose density is not much more than 2, it may be at once inferred, that the density of the earth increases from the surface towards the centre.

7. The amount of the earth's oblateness leads to a similar result. Were the earth of uniform density throughout, the oblateness would be $\frac{1}{234}$. Were it infinitely dense at the centre, and infinitely rare at the surface, the oblateness would be $\frac{1}{578}$. Now, as the oblateness is $\frac{1}{300}$, which lies between these limits, the density must decrease from the surface towards the centre.

II.

OF THE TEMPERATURE OF THE CRUST OF THE EARTH.

8. The temperature of the surface of the earth, although rarely exactly the same with, never differs more than a few degrees from, that of the portion of the atmosphere which is

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in contact with it. This superficial temperature is therefore subject to continual variations during the alternations of day and night, and the vicissitudes of the seasons. But when we penetrate beneath the surface of the earth in digging pits, in sinking mines, or in natural caverns, we find that the extremes of temperature gradually approach, until a depth is reached at which the thermometer retains a constant height. This constant temperature is, as nearly as can be ascertained, the same with the mean annual temperature of the atmosphere at the surface above. The thermometer first assumes a constant indication, in extreme climates, such as our own, at depths of from 30 to 40 feet; but in climates where the variation of temperature is less, the depth at which a constant temperature first occurs is less also, and, in equatorial islands, does not exceed two or three feet.

9. At depths greater than that at which a constant temperature first occurs, the temperature at a given point is constant also, but this constant temperature of each different depth increases as the depth increases. It has hence been calculated, that at a depth of about 3000 yards, the temperature will be as great as that at which water boils.

10. It is therefore obvious, that the mean temperature of the body of the earth is greater than that of its surface, and as it is situated in a space much colder than itself, heat must be constantly escaping by radiation in all directions. The earth would therefore be continually growing colder, were there not some extraneous source of heat.

11. We find such an extraneous source in the rays of the sun, and it is obvious that these two causes must, after some period, less or greater, exactly balance each other, and the mean temperature of the earth become constant. We know, from astronomic facts, that this state of constant mean temperature in the earth has been very nearly reached at the present day, and that no perceptible decrease of mean tem-

perature has taken place for more than 2000 years. There are, however, some who maintain that the state of equilibrium between solar and terrestrial radiation has not yet been reached, and that the earth is still decreasing in temperature, although so slowly that it cannot be detected by the method to which we have referred.

III.

OF THE DISTRIBUTION OF LAND AND WATER ON THE SURFACE OF THE GLOBE.

12. The solid crust of our globe is far from being level, but presents a succession of prominences and cavities irregularly distributed. The deepest of these cavities communicate with each other, and are filled with a great mass of water, which we call the ocean. This is of such extent as to cover, at least, three-fourths of the surface of the globe. We distinguish different portions of this mass by names, although there is no precise limit between these several portions, and although to a general and systematized view the surface of the globe presents the aspect of a single great ocean, in which are situated two great and an infinite number of small islands. The two great islands are the Old and New Continents; of the smaller islands New Holland is the most extensive.

13. In order to exhibit this arrangement of the surface of the globe in the clearest light:—take a terrestrial globe, elevate its southern pole 50°, and bring New Zealand to the meridian, the hemisphere which now lies above the horizon is wholly covered with water, except many small islands, the southern extremity of South America, New Holland, and the Indian Archipelago. In the opposite hemisphere and immediately adjacent to the part above the horizon, are por-

tions of the ocean of much greater extent of surface than the lands we have mentioned. The opposite hemisphere being brought up, the two great islands will be seen, separated by a channel of small extent when compared with the residue of the ocean. This channel is the North and South Atlantic; it is widest between the southern extremities of Africa and South America, and although irregular, gradually decreases in width, until, having passed the north pole, it communicates with that part of the great ocean known as the Pacific, through Behrings Straits.

14. Besides the main ocean and this great arm, both have numerous branches, which go by the name of seas, gulfs, and bays. The most important of these are the Mediterranean, Baltic, and Carribean seas.

15. The continents also enclose large masses of water which are called lakes, or even, when of great extent, although improperly, seas. On the old continent, the most extensive of these is the Caspian, and on the new, Lake Superior. Some of these lakes communicate with the ocean by channels, through which their surplus waters are discharged into its basin as a common reservoir. Others have no outlet. All lakes which have outlets contain fresh water alone; those which have no outlet are salt.

16. The channels by which the surface waters of the land are carried into the ocean are called rivers. These differ extremely from each other in size; those which are smallest are styled rivulets or brooks; in America those of mean dimensions are usually called creeks, which, although not the legitimate application of the term, is, notwithstanding, convenient, as a term is obviously wanted to distinguish such streams as the Mississippi and Amazons, from those of no more extent than the Thames or the Seine.

IV.

OF THE INEQUALITIES OF THE LAND.

17. Considerable portions of the earth's surface have little more slope than is necessary to prevent the surface water from becoming stagnant. Such level surfaces are called plains, or, when elevated, table lands.

18. Abrupt elevations above the level surface are called hills, and, when of great height, mountains.

19. Valleys are cavities, or depressions beneath the general level of the surface. They may be formed by surrounding hills, or hollowed out of table lands. A valley is distinguished from the surrounding high lands by the nature of their respective curvatures; that of a valley being concave, and that of the hill or mountain, convex; and the limit is where the curve changes its character from one of these forms to the other.

20. Every valley contains the bed of a stream or river. Such stream occupies the line of greatest slope which can be drawn in the valley.

21. It sometimes happens that a valley is of small extent, and terminates speedily at the shores of the ocean; more frequently the more elevated valleys communicate with others at a lower level; these again merge in others. The streams which drain the several valleys unite their waters, until they finally form a single great river. The courses of such streams, if drawn upon a level surface, present the appearance of the trunk of a tree and its branches.

22. The whole system of valleys which thus unite their waters in a single stream is called the basin, or the valley of that stream. It may be separated from the neighbouring portions of a continent by supposing lines to be drawn through the sources of the several streams.

23. The valley of a stream is sometimes divided into two or more separate basins by ridges of mountains, through ravines in which the river forces its way. Of this we have an instance in the Hudson, and one still more remarkable in the Susquehannah. The main branch of the latter river occupies a shallow basin, in a country whose general slope is directed towards the lakes; and in making its way to the sea it passes through five distinct ranges of mountains.

24. Mountains may be either isolated, combined in groups, or united in ridges. Groups of mountains are generally arranged around a central eminence, which has a greater height than any which surround it. In some cases, the whole group is considered and named as if it were a single isolated mountain. Of this we have an instance in Ætna, which is composed of a number of separate mountains, lying upon the slopes of a greater central peak.

25. Chains of mountains have sometimes a constant direction throughout their whole extent. Such is the case with the Pyrenees; at other times they suddenly change their direction, or follow irregular lines. In spite of any irregularity, it may be generally remarked, that principal chains of mountains have a direction analogous to that of the land in which they are situated.

26. The breadth of chains of mountains is extremely variable, and they sometimes exhibit a continuous crest, varying but little in height; in other cases and more usually, the crest is deeply serrated, so that the chain may be considered as made up of a number of detached mountains. The highest points of a chain are called peaks.

27. The direction of a chain of mountains is usually pointed out by imaginary lines joining the peaks. This is, in many cases, a rhumb-line, or directed constantly to the same point of the compass.

28. What may appear from a low position as a chain of mountains, is often no more than the edge of a table land. There is a famous instance of this in the line intended as a division between the territories of the United States and those of Great Britain. In sailing up the St. Lawrence, the southern shore presents the aspect of a continuous chain of mountains, while, in approaching that river from Maine or New Brunswick, no mountains are to be seen, in consequence of the country being an elevated plain, of which the heights seen from the river are the northern and western slope.

29. The lowest points in a serrated chain of mountains are called passes or gaps. These are the summit levels of valleys which traverse the chain. The slope of a chain is usually estimated as formed on each side of the line which marks its direction by passing through the peaks. A better mode of defining the slope is, by a line passing through the summits of the several gaps. By this method the slopes of the chain are made to correspond with the valleys or basins of the streams which take their rise in them.

It rarely happens that the opposite slopes of mountains exhibit any approach to uniformity, being, in many cases, abrupt on one side and gentle on the other. In many instances the slopes are composed of a number of transverse ridges separated by valleys. In some cases the slopes are formed by a succession of steps, each having the character of a plain. Chains of mountains are sometimes single; at other times they are composed of several parallel ridges. The valleys included within systems of mountains may therefore be either transverse or parallel to the general direction of the ridges.

30. The heights of many mountains have been measured.

The most interesting of these measures are contained in the following lists:—

AMERICA.

Nevado de Sorata	(Upper Peru)	25,250 feet
Illimani	(Do.)	24,000
Chimborazo	(Quito)	21,425
Cayambe	(Do.)	19,505
Cotopaxi	(Do.)	18,875
Mt. St. Elias	(N. W. Coast)	18,000
Popocatepetl	(Mexico)	17,717
Orizaba	(Do.)	17,272
Sierra Nevada	(Do.)	15,701
Mt. Fairweather	(N. W. Coast)	14,913
Coffer of Perote	(Mexico)	13,500
Volcano	(Otaheite)	10,900
Blue Mountains	(Jamaica)	7275
Solfaterra	(Guadaloupe)	5107
	(North Carolina)	7000
Mt. Washington	(New Hampshire)	6600
Saddle Mountain	(Massachusetts)	4000
Round Top of Catskill		3900
Fishkill Highland		1500
Anthony's Nose		1200

EUROPE.

Mount Blanc	(Alps)	15,662
Mount Rosa	(Do.)	15,084
Jung Frau	(Do.)	13,714
Ortler	(Tyrol)	12,855
Mulahasen	(Grenada)	11,664
Malahite	(Pyrenees)	11,421
Mont Perdu	(Do.)	11,187
Ætna	(Sicily)	10,954
Budosch	(Transylvania)	9592
Somnis	(Carpathians)	8862

EUROPE.

Monte Rotondo	(Corsica)	8760 feet
Sneehaten	(Norway)	8203
Vellino	(Appenines)	7950
Athos	(Greece)	6789
Mont d' Or	(France)	6280
Snaefells Jokul	(Iceland)	5249
Puy de Dome	(France)	4813
Black Point	(Spitzbergen)	4500
Ben Nevis	(Scotland)	4050
Vesuvius	(Naples)	3935
Snowden	(Wales)	3555
Schehallien	(Scotland)	3407
Hecla	(Iceland)	3323

ASIA.

Davalageri	(Himmalaya)	25,746
Javahir	(Do.)	25,661
Arrarat	(Armenia)	17,000
Elborz	(Causasus)	16,434
Peak	(Frontier of China and Russia)	16,848
Ophir	(Sumatra)	12,960
Mount Libanus	(Syria)	9534
Altai	(Siberia)	7224

AFRICA.

The heights of the mountains in the interior of this continent are unknown. Some of them must be great, and, amongst the rest, it is known that the Atlas rises beyond the limit of perpetual congelation, and therefore exceeds 13,000 feet. Of the mountains of the islands and the southern extremity, the following are the most important:—

Peak of Teneriffe,		12,171 feet
Ambotismene	(Madagascar)	11,405
Pieton des Neiges	(Isle of Bourbon)	10,061
Pico	(Açores)	7913
Table Mountain	(Cape of Good Hope)	3816

31. Of the gaps or passes which are traversed by roads, the following are the most remarkable :—

Chullunquani	(Cordilleras)	15,226 feet
Paquani	(Do.)	14,840
Gualilas	(Do.)	14,075
Tolapalca	(Do.)	13,672
Mount Cervin	(Alps)	10,187
Port d' Oo	(Pyrenees)	9843
Estanbe	(Do.)	8402
Furka	(Alps)	8300
Great St. Bernard	(Do.)	8270
St. Gothard	(Do.)	7192

32. The highest inhabited part of the globe, as far as has been ascertained, is at Aneomarca, in the Cordilleras.

The highest part of the city of Potosi		15,722 feet
Quito		9541
La Plata	(Bolivia)	9331
Santa Fe de Bogota		8731
Arequipa		7800
Mexico		7471
St. Veran	(Alps)	6693
Heas	(Pyrenees)	4807

33. The limit of perpetual congelation is as follows :—

Equator - - - -	15,800 feet
20° - - - -	15,200
45° - - - -	9350
65° - - - -	4900

V.

DESCRIPTION OF THE TWO GREAT CONTINENTS.

34. The eastern continent may be considered as composed of a large mass of land, from the western side of which three principal peninsulas, of very different dimensions, project. The greater compact surface includes the whole of Asia, and Russia in Europe. The three peninsulas are, the Scandinavian; Europe, with the exception of Scandinavia and Russia; Africa. The second of these includes a number of lesser peninsulas, which it is not our purpose to describe.

35. The interior of Africa is so little known, and Europe is so much cut up by gulfs and seas, that any attempt to reduce its mountains and plains to one general system, must fail. But in Asia no such difficulty exists. We find the northern part of Asia to be composed of one vast extended plain, and that this plain is produced into Europe. Thus a traveller may leave the foot of the Pyrenees, and proceed to Paris; thence through Belgium, Northern Germany, Poland, and Russia, in Europe, to Kasan; thence again through Siberia, until he reaches the frozen ocean, without meeting, in his journey, any eminence of more than 600 feet in height, with the single exception of the Oural mountains. These divide this vast plain into two unequal parts, but are themselves of but moderate elevation.

This plain is bounded to the south by a system of mountains, which, in Asia, is distinctly marked as made up of four great chains. These are as follows:—

(1.) The chain of the Altai begins at the north-eastern extremity of Asia, and can be traced in a direction a little south of west to the eastern side of Lake Aral. Its most lofty point appears to be the mountain known as the Golden or Little Altai, whose height has been given at 7224 feet. The same rhumb line produced, passes over the Atlas, but it would be more probable to consider, as belonging to this chain, the Caucasus, the Carpathian mountains, the Vosges, the Cevennes, and the Pyrenees.

(2.) The celestial mountains (Thian Chan) of the Chinese. This chain rises on the shores of the Pacific to the north of the peninsula of Corea, and can be traced to the neighbourhood of Samarcand. Its most lofty point is called Bogdo and is covered with perpetual snow and glaciers. In the same line with this we find Arrarat, and may consider as lying in its prolongation, the northern mountains of Asia Minor, of Thrace, the Alps, and those of the north of Spain.

(3.) The chain of Kuen-lun, which is first found separating the basins of the two great rivers of China, and rising at the sources of the Yellow River, above the limit of perpetual congelation. Passing through Thibet it enters Persia, under the name of Hindoo Kho, and, after an interruption by the basin of the Euphrates, rises again under the name of Taurus, in Asia Minor. Its mean latitude is 35°, and may thus be considered as comprising the mountains of Greece, and those of the south of Spain.

The two last named chains may be almost considered as forming one system, in consequence of the number of transverse ridges which unite them, and the elevated table lands they enclose.

(4.) The chain of Himmalaya rises from the Pacific, opposite to the island of Formosa, and reaching to the greatest heights which have yet been measured, passes to the north of the two Indies, until it appears to merge in the Hindoo Kho. Pursuing its mean direction, we however find in the same line, the southern mountains of Persia, those of Syria, and Atlas.

Africa, as far as we can learn, contains a separate system.

Another system is to be found in Europe, composed of the Norwegian Alps, the mountains of Scotland, Wetmoreland and Wales, and which, falling in elevation, may be traced into Cornwall and Brittany.

36. The new continent, like the old, presents the appearance of a great plain, bounded on one side by a continuous system of mountains. This great plain is divided into two parts by the Carribean Sea, and Gulf of Mexico, which also give the continent the form of two peninsulas, united by a narrow isthmus. In the northern peninsula, the great plain includes the vast basins of Mackenzie's River, and the Mississippi; in the southern, those of the Orinoko, Amazons, and La Plata. It is limited by the ocean in Labrador, Florida, and at the mouths of the last named rivers. In other parts it is bounded to the east by mountains.

Beginning at the southern extremity of the continent, the system of mountains which bounds this plain on the west comprises but a single ridge, whose height does not at first exceed 6 or 7000 feet. In lat. 37° south it rises to 16,000 feet, in the Peak of Antucos. Between the 20th and 14th degree of south latitude, the system divides into two distinct chains, enclosing a great table land, in which is situated Lake Titicaca; and here we find the loftiest summits, Sorata and Illimani. The two chains again unite and form but one, until they reach the 8th degree of south latitude, when they fork and enclose the table lands of Quito and Santa Fe. The eastern chain of these two ridges terminates abruptly in the Carribean Sea; the western sinks into mountains of moderate elevation at the Isthmus of Panana, but speedily assumes greater dimensions, dividing again into two chains, which enclose the great table lands of Mexico. Thence it is to be traced northward, under the name of the Rocky Mountains, until it terminates on the shores of the frozen ocean. The most lofty parts, which are well known, of this system in North America, are in sight of the city of Mexico; but, according to the statements of the surveyor of the Hudson's Bay Company, the mountains near the sources of the Columbia are even more elevated, and yield but little to the Himmalaya in this respect.

37. In the United States, Guiana and Brazil, the great American plain is bounded on the east by mountains. In the United States these do not rise to any great height, and may be considered as forming a system to which the name of Apalachian is with propriety given. Five distinct ridges may be traced in this system. The outer takes its rise on the frontiers of Canada, and is at first called the Green Mountains; it assumes a height of 4000 feet in Massachusetts, under the name of the Saddle Mountain. Thence, going under the names of the Taconic and Hoosic Mountains, it merges in the Highlands of the State of New-York. In New-Jersey it is known under the name of Schooley's Mountain, and appears in Pennsylvania at Durham. In traversing the greater part of the last named state, it sinks to hills of moderate elevation, but rises again in Maryland, and is broken by the Potomac at Harper's Ferry. It thence forms a continuous range under the name of the Blue Ridge, through Virginia, North and South Carolina, and the northern part of Georgia. In North Carolina this range reaches its greatest height, which is about 7000 feet. The White Mountains in New-Hampshire probably belong to this range, although separated by the valley of the Connecticut. The height of Mount Washington, the most elevated of the last-named group, is 6600 feet. There is another outlying group in North Carolina, which is the site of rich gold mines, and a parallel ridge is to be traced in Virginia, about twenty miles east of the Blue Ridge.

The second ridge makes its first appearance in the state of New-York, in the angle of the Esopus and Rondout

Creeks, under the name of Shawangunk. It assumes in Pennsylvania the name of the Blue Mountain, and spreads out into a vast number of confused ridges, which have the aspect of a table land cut by deep water courses. The most elevated parts go under the name of Sideling Hill. In Virginia the Cacapon seems to belong to this range, and the confused groups are traced into Georgia. The great Alleghany range seems to take its rise in Hamilton county, New-York. It is thence traced across the Mohawk, which forces its way through it at the Little Falls. About twenty miles south of the Mohawk it turns suddenly to the east, and coming within sight of the Hudson, forms an angle in the Pine Orchard, where it changes its direction to the south-west, and presents an imposing appearance under the name of the Catskills. Following the same direction it enters Pennsylvania under the name of Moosick, and shortly afterwards is first called Alleghany. In Maryland it is known as the Back Bone, and again in Virginia as Alleghany. It may also be traced into Georgia. The remaining two ridges need not be described; their most northern and western limit in the state of New-York is at the southern end of Canandaigua Lake. The system turns to the westward in the state of Georgia, but which of the ridges in particular are produced is not well ascertained. We have no defined account of the direction of the ranges in Caraccas, Guiana and Brazil, but there is a remarkable similarity, in geological character, between those of the latter country which are most accessible and the outer range of the Apalachian group.

VI.

OF ROCKS AND FOSSILS.

38. The bodies which we find in the solid crust of the earth are not wholly mineral. The remains of vegetable and animal bodies are found imbedded in the upper beds, often but little altered, and in other cases the forms of organized beings are distinctly visible, even where all trace of the matter of which they were once composed has long since disappeared.

39. The mineral part of the earth's crust is made up of masses, of greater or less extent, which, with the exception of loose beds of recent origin, are called rocks.

40. Rocks may be composed of a single mineral species, or made up of several. Rocks are numerous, although less so than the different mineral species, and their great variety shows incontestibly the influence of many different causes and modes of formation.

41. Rocks which are of similar or probably nearly cotemporaneous origin, are arranged in groups, which are called formations. And these again may be considered as greater or less, a great formation often including a number of lesser ones. Great formations may again be arranged in orders and series.

42. Rocks rarely run into each other, and even contiguous portions of the same rock may be divided from each other. The lines of separation are called joints.

43. Joints may be divided as follows, viz:

(1.) Joints of texture, which depend principally on crystaline structure, and are therefore rather the objects of mineralogy than of geology;

(2) Joints of stratification, which divide formations into a number of layers, that when viewed throughout any considerable extent are parallel to each other, although this parallelism may not be perceptible within small limits.

(3.) Joints of injection, which traverse rocks in every possible direction, and are filled up by rocks or mineral species essentially different from those they traverse. Such joints, when of no great thickness, are called veins, and are the principal source of the useful metals. Joints of injection, when of wide extent and nearly vertical, are known by the name of dykes, and contain only earthy minerals. It is now known that the nuclei of most mountains are only joints of injection of still greater size.

(4.) Fissures differ from veins in containing no extraneous minerals. The most remarkable of these are found in trap and basaltic rocks, dividing them into prismatic masses.

(5.) Faults are dislocations of stratified rocks, on the opposite sides of which a given layer is found at very different levels. Hence it may be assumed, that it has at this point been suddenly elevated or depressed. Faults may be occupied by dykes. A fault is well known in England, in which the level of the strata is changed as much as 900 feet.

45. The remains or traces of organized matter are said to be fossil. Fossils may occur in the following different states:

(1.) Retaining their original chemical constitution;

(2.) Partially altered, and some of their elements recombined under the influence of chemical and physical causes;

(3.) Wholly changed, so that no more than the form and elements remain, but the latter in new states of chemical combination;

(4.) Petrified, when the whole of the organized matter has disappeared, and its place is occupied by a mineral whose external figure is precisely that of the organized body;

(5.) In impressions, where no other trace is left of the organized body than a mould of its surface in rock. The evidence of the existence of the organized body may be compared to that by which we know a seal has existed when we see its impression on wax,

46. Fossils are important distinctive characters, by which to determine the identity or analogy of formations; hence some knowledge of the organic world is essential in geology.

Organized beings are divided into two great kingdoms, the animal and vegetable. These are again ranked in grand divisions, classes, orders, families, genera, and species.

The animal kingdom has four grand divisions, viz. :

1. Vertebratæ;
2. Articulatæ;
3. Moluscæ;
4. Radiatæ;

47. The following is the arrangement of vertebrated animals :—

Class.	Order.	Family.	Instances of Genera.
I. MAMMALIA.	BIMANA,		Man.
	QUADRUMANA,		Monkey.
	CARNARIA,	Plantigrade,	Bear.
		Digitigrade,	Dog.
		Amphibia,	Seal.
	MARSUPIA,		Opossum.
	RODENTIA,		Rat.
	EDENTATA,	Tardigrade,	Sloth.
		Ordinaria,	Ant Bear.
		Monotreme,	Ornithoryncus.
	PACHYDERMATA.	Proboscidia,	Elephant.
		Ordinaria,	Hog.
		Solipes,	Horse.
	RUMINANTIA	Camel,	
		Lama,	
		Chevrotain,	Musk.
		Giraffe,	
		Deer,	
		Antelopes,	
		Goats,	
		Sheep,	
		Bos,	
	CETACEA,	Herbivorons	
		Ordinaria,	Whale.

Class.	Order.	Family.	Instances of Genera.
II. Aves.	The orders, families, and genera of birds are of little importance in geology.		
III. Reptilia.	Chelonia,		Turtle.
	Sauri,	Extinct,	
		Crocodile,	
		Lizard,	
		Iguana,	
		Chameleon,	
	Ophidia,	Angues,	
		Serpentes,	
	Batrachia,	Grana,	Frog.
		Triton,	Newt.
IV. Pisces.	Fish are arranged in two sections, the bony and the cartilaginous.		

48. Of Articulated animals there are four classes :—

1. Crustacea, as the crab ;
2. Arachnides, as the spider ;
3. Insecta,
4. Annulata, as the earthworm.

49. Of Moluscous animals the softer parts generally disappear when they become fossil. Their only important character in geology, therefore, is derived from their shells. These may be Univalve, Bivalve, or Multivalve, and the two former may be either unilocular or multilocular, according as the space within the shell is composed of a single chamber, or of many, separated by partitions.

50. Of radiated animals it is only necessary for our purpose to be acquainted with the classes of Echinodermata and Polypi. The former includes the Asterias or star-fish, the Echini or sea-eggs, and the Encrinites. The latter comprises Madrepores, Corals, and Sponges.

Such is the progress that has been made in the study of comparative anatomy, that it is now possible, from the examination of a single bone, to determine the species, genus, and family of the animal to which it belonged. In the case of fish, a single scale is sufficient for the same purpose. For bringing the first method to perfection we are indebted to Cuvier, and for the latter to Agassiz. It is, however, due to one of our own countrymen, the late Dr. S. L. Mitchell, to mention, that more than twenty-five years ago, he publicly stated, that he was aware of the possibility of classifying fish from no more than a single scale, and had made some progress in such determinations.

51. The vegetable kingdom is made up of three grand divisions, viz:—

1. Agamia;
2. Cryptogamia;
3. Phanerogamia.

52. Of Agamia, two families only are found in the fossil state, the Confervæ and Algæ.

53. Cryptogamia form two series, the cellular and the vascular. Of the former the family of Mosses, and of the latter those of Equisetæ, Ferns, Chara, Lycopodia, Marsilia, are found fossil.

54. Of the Phanerogamia there are three series,—the gymnosperms, the monocotyledons, and the dicotyledons. Of gymnosperms, two families, the cycades and the coniferæ;—of monocotyledons, the naiads, palms, lilies, grasses;—of dicotyledons, Amentæ, Juglans, Acer, Nymphæa, besides various specimens whose families cannot be easily determined, are found in the fossil state.

Our limits and object do not permit us to enter fully on this subject.

II. GEOGNOSY.

OF FORMATIONS.

55. It has been a disputed question, whether the solid crust of the globe were formed at a given epoch, and called into existence in the state in which we find it, or whether it have been the result of a succession of actions, whose influence is continued down to the present day. The former idea has been, at last, wholly abandoned, and we shall, as we proceed, develop innumerable facts, by which it will be shown, that the present state of the crust of the globe has been attained by slow and gradual steps, under the action of causes, which, if perhaps less intense, are still to be perceived slowly changing the surface of the earth. The period which has thus been occupied in bringing the land into its present state, cannot be defined in years, or even centuries, but may readily be divided into geological epochs.

56. The term formation is, in some degree, vague; in its most limited sense it is confined to rocks of identical character, or in which some one rock predominates. In a wider sense, it includes all the rocks which can be assigned to a single geological epoch.

57. When rocks are stratified, or when their character is such as leaves no doubt that they have been deposited either chemically, or mechanically, from water, we can judge without difficulty of their relative date, by the mere order of their superposition. It being evident, in the latter case, that the lower rock must have been first deposited, and probable that such was the fact, even where the cause of the formation has

not been aqueous. In spite of this mode of examining the relative date of formations, there are still many parts of the crust of the earth which it is difficult to assign to precise geological epochs. This may happen from various causes:

(1.) We may have no means of determining their exact position.

(2.) The same rock may occur in formations which, for other reasons, we should consider as belonging to different epochs.

(3.) A rock may not belong to the series in which it is found, but may have been subsequently introduced, cutting through others more ancient than itself, or being intercalated among them.

(4.) It is yet possible that the order in which formations succeed each other, may not be identical in all parts of the globe. No more than a part of Europe has been fully examined, but every new region which is explored seems to confirm that the order which exists in that quarter of the globe is, in its general features, the same which governs the formations of other countries.

The difficulties are enhanced by the fact, that whole formations of great extent, which are found in some places, are wanting in others.

58. We obtain our knowledge of the order in which rocks are superposed, by the outcrop of inclined strata or beds; by digging pits or sinking mines; aud by the appearances presented on the flanks of mountains, and the sides of deep valleys.

59. Some formations are going on under our own eyes, and the date at which the causes that produce them began to act, cannot be referred back more than a few centuries. Such formations may be styled modern. There are others which had assumed the character and position in which we now find them, before the modern formations began. The

latter may be called ancient. Intermediate between these we find the evidence of one or more great catastrophes, by which the whole surface of the present land was exposed to the action of water, and actually submerged. The deposits from those floods we shall rank with modern formations, under the term of diluvial.

60. Modern formations may be distinguished into four orders:—

1. Alluvial;
2. Chemical;
3. Diluvial;
4. Volcanic.

61. Ancient formations may be either stratified or not. The ancient stratified formations may be divided into five orders:—

1. Superior;
2. Supermedial;
3. Medial;
4. Submedial;
5. Inferior.

Ancient rocks, not stratified, are arranged in six orders:—

1. Granitoid;
2. Porphyritic;
3. Ophiolitic;
4. Trachytic;
5. Trapp;
6. Volcanic.

I. MODERN FORMATIONS.

ORDER I.—ALLUVIAL.

62. Alluvial formations may be either of animal or vegetable origin, or of one wholly mechanical.

Vegetable formations are intimately mixed with decomposed earthy matter; while those of mechanical origin contain organic substances, either retaining their structure, or decomposed.

63. The formations of animal origin are principally to be met with in the form of coral reefs. This action is most intense in the Pacific Ocean, and it has even been supposed that islands have been raised from the depths of the sea by the labours of the coralline animals. More close investigation seems to lead to the conclusion, that the work of the species which are capable of forming continuous banks, is limited to the depth of about 30 feet; and that a shoal, arising from some other cause, must have previously existed.

Vegetable alluvial formations are called by Brogniart, *Phytogene*, and are two in number:—*Humus*, or vegetable mould, and turf, or peat.

64. The formation called *Humus* is almost coextensive with the surface of the land, being found every where, except in the most barren deserts, and on the steepest declivities. It is never of any great thickness, and this is one of the most satisfactory proofs that the present geological epoch is of modern date, compared with the whole duration of the earth's existence.

65. Turf is composed almost wholly of aquatic vegetables, and is found in basins which appear to have once been lakes, in which the water, without being absolutely stagnant, had but small velocity. In such situations, after the vegetables had ceased to live, decomposition had not commenced, and the dead plants have served as the bed on which others have grown, without undergoing putrefaction. In the beds of turf which belong to alluvium, the cause is still in action, so that if a part be removed, as is done in some countries to convert it into fuel, the space will, after a time, be filled with

a new growth of turf. Trees are frequently imbedded in turf bogs, and, of some of them, trees form the principal part.

66. The mechanical formations of alluvial origin are wholly produced by the action of water. They are always found in the neighbourhood of existing water-courses, and in positions either actually within their present sphere, or such as may have been reached by them, without any change in the general circumstances of the earth's surface. They are made up of beds of sandy, clayey, or marly mud, of sand, gravel, and pebbles, and of collections of rolled masses or boulders. The mud is frequently coloured black or brown by the carbon arising from the decay of organic matter; and it frequently exhales offensive gases, which are unwholesome. This formation covers the valleys of streams forming what are called by our settlers, bottom lands—extends into the sea at the mouths of rivers, forming banks and shoals, and constitutes deltas, where rivers of the largest size meet the ocean.

67. Deltas have been formed, or have much increased, within historic periods, and are still, in many cases, extending themselves into the ocean. The space now occupied by the Delta of the Nile is represented by Herodotus to have been a gulf in the time of Moeris, and we can easily believe how rapidly it must have formed, when we observe the vast quantity of sediment, about one part in four, contained in the water of the Nile. At present, however, it is no longer on the increase, and an obvious reason has been found why it should not; for, it has been protruded so far as to meet a rapid current, which sweeps from the Straits of Gibraltar along the shores of Africa.

At the mouth of the Rhone, a Roman road, which once followed the line of the beach, is now several miles inland. Notre Dame des Portes, a harbour A. D. 898, is now a league; Psalmodi, an island A. D. 815, two leagues from the sea; and the tower of Tignaux, erected on the shore so late as 1737, is now a mile distant from it.

The Delta of the Po has made still greater encroachments on the Adriatic. The town of Adria, whence the sea derived its name, a seaport in the time of Augustus, is now twenty miles inland, and Spina, its predecessor, as a harbour, was eleven miles from the sea when Adria was built.

The Mississippi has protruded the cape in which it finds its place of discharge, fifty miles into the Gulf of Mexico, since its mouth was first discovered, and has advanced it thirty miles since the city of New Orleans was built. Where rivers, carrying large quantities of earthy matter, meet a sea influenced by powerful tides, a continual struggle takes place between the tendency of the one to form land and the other to sweep it away. Islands are continually forming and carried away, and, in many such cases, although changes are going on, the extent of delta appears to have reached its limit.

68. Beds of sand and gravel, and collections of solid masses called boulders, are found in the same position in relation to rapid streams, as beds of mud to those of more steady and gentle current. With them we may class the downs or sand hills, which are thrown up by the surf of the ocean, and the beaches of sand and gravel which it forms as a boundary to its own violence.

69. In alluvial formations no other metal is found in any quantity, except iron. This occurs in the shape of sand, and of bog ore, in the lower parts of basins, occupied by turf or alluvial mud. Some of its sands and gravels appear to contain gold. The bog ore, however, is rather of chemical than alluvial origin.

70. Of organic remains, alluvium contains the relics of man, and of all the animals which now inhabit the earth. The latter are sometimes found in countries where they have long ceased to exist; as, for instance, the bones of the beaver in

Great Britain. Other remains are found, although rarely, of animals, no living instance of whose species is now known to exist, as the elk of Ireland. In the first case, however, the animal is one well adapted to the climate; and traditions, in both Wales and Scotland point to a time at which it was well known. In the latter case, we need not look to a date for the existence of the fossil elk, more remote than the present epoch of the earth's geological history, for it is not the sole instance of a whole species having become extinct, not merely in a single country, but throughout the globe, and it is more than probable that others will disappear before the powers of man. Some geologists, however, consider the fossil elk as belonging to a more ancient formation.

We not only find, in alluvium, the remains of man himself, but those of the works of human art. These, in some cases, carry us back to periods antecedent to any authentic history. Thus the stone axes and arrow heads of England mark a state of civilization no more advanced than that of our own Aborigines; and canoes have been discovered in France, in these formations, like those of the Indians, and South Sea Islanders.

71. Besides the vegetable matter contained in the swamps and mud, large beds of trees are found in the alluvium, and particularly in the deltas of some rivers. This is particularly the case in the delta of the Mississippi; and in some of its arms and branches, they have formed rafts, which impede the navigation for hundreds of miles. These trees are such as grow, at present, on the banks of the stream.

ORDER II.—CHEMICAL.

72. The modern chemical formations may be classed as calcareous, silicious, saline, inflammable, and metallic.

73. Calcareous formations of this order take the form of stalactite and stalagmite, of pisolite, and of travertine; they also occur in masses of alluvial sand and gravel, which they convert into silicious limestone, and calcareous pudding stones. All such formations are due to the solution of carbonate of lime, in water containing excess of acid, and its subsequent deposit, as that excess escapes.

Travertine is a carbonate of lime which occurs in concretions of a granular structure, or even, occasionally, crystaline. It is sometimes so firmly aggregated as to be liable to be mistaken for rocks of far more ancient date.

These calcareous formations are partly cotemporaneous with the alluvial, and partly of more ancient date. The latter we shall have occasion to speak of hereafter. Of such as are at present going forward, we may cite the following instances:—

1. Travertines forming in Italy, as cited by Davy, in his "Consolations in Travel."

2. A travertine forming near Batavia, in Java.

3. Travertine forming in the marshes of the great plain of Hungary, which becomes sufficiently solid to serve as a building stone. It contains shells which are unaltered, and belong to the species found at present living on the spot.

4. A calcareous rock, containing shells and aquatic vegetables, which is daily making at the bottom of a lake in Scotland.

5. Innumerable instances of stalactite and stalagmite in grottos.

Such formations are not confined to the land, and to fresh water, but are taking place in the ocean, or in lands recently conquered from it.

Of this we have proof:—

1. In the concretions forming in the Mediterranean, opposite Messina. Here the beach, which is a sand, composed of

grains of quartz, felspar, hornblende, &c., has been observed to become so firmly aggregated in less than twelve years, by a calcareous cement, that it may be used for mill-stones.

2. A similar rock forms on the coast of Ceylon, between Colombo and Negombo.

3. A coarse calcareous sandstone, on the windward side of the island of Guadaloupe.

In this formation a human skeleton was found imbedded, and was urged as proof that the date assigned in Scripture for the creation of man was erroneous. More accurate examination has shown the rock to belong to the order we are treating of, and to be long posterior in origin even to diluvium.

4. The delta of the Rhone has been almost wholly converted into a solid rock by a calcareous cement.

74. Modern silicious formations are extremely rare, and are principally remarkable in their connection with the more ancient silicious rocks, of some of which they serve to explain the origin. This, as far as respects the modern formations, is from solution in water. The best instances of this sort are:—

1. Cylindroidal concretions of silica, found in caverns of the Isles of France and Bourbon;

2. Silicious stalactites, deposited by the vapour of water on the sides of the crater of Lancerota;

3. The silicious deposit of the Geysers in Iceland;

4. The deposits of certain warm mineral springs, such as those of Mont d'Or in France, and Poorgotha in India.

Allophane, a mixture of the hydrates of silica and alumina, is ascribed to a similar origin.

75. The salts which are at present forming in alluvial formations are, natron and borax, which are deposited by certain lakes; nitre and nitrate of lime; alum, and the sulphates of soda and magnesia. With them we may class

sulphurous and sulphuric acids, which are met with in the neighbourhood of volcanoes, and muriatic and boracic acids.

76. Of inflammable bodies of modern origin we may cite sulphur, either sublimed from volcanoes or deposited in the form of hydrate from springs charged with sulphuretted hydrogen, bitumen, naptha, and petroleum.

77. Among metallic bodies it appears to be a well-established fact, that the sulphurets of iron and copper are formed on some occasions, among modern formations. We have ourselves seen a vegetable petrifaction found in alluvium, wholly composed of pyrites. Turf has also been found containing pyrites. The blue phosphate of iron is also formed under our eyes, but appears to be derived from the white phosphate of more ancient date.

The hydrated oxide, known as bog and meadow ore, to the former of which we have referred in speaking of alluvial formations, also belong to the modern period; and with it may be ranked the ferruginous pudding stones.

78. The same organic remains which have been cited under the head of Alluvium, are found in the newer chemical formations. In those of more ancient date they are the same as in the diluvium.

ORDER III.—DILUVIAL.

79. Diluvial formations are coextensive with the surface of the land, being found everywhere, except on the steepest slopes, or in places within the reach of existing water-courses. In the latter case they are not to be considered as wanting, but are confounded with the deposits of alluvium. They are made up of beds of mud, clay, marl, sand, and gravel, and collections of boulders; they include in some cases turf and beds of fossil wood. The turf of diluvium does not exhibit

any vegetable life, and does not renew itself. The fossil wood has been partially mineralized by a new combination of its elements. The modern chemical formations occur in the midst of the diluvial, showing that the causes to which the former are due have acted both during the alluvial and diluvial period.

The beds of mud, clay, marl, and sand, which belong to this diluvial period, are most easily distinguished by their position; all such as are beyond the reach of existing water-courses must be ranked in this order.

The gravel and boulders of diluvium are not only distinguished by position, but by well marked characters. The boulders of diluvium are often much larger, and can be traced to a far more distant locality than those of alluvium, and they, as well as the pebbles of the gravel, are much less worn than are those found in existing water-courses.

80. Diluvial formations are not only more extensive than any of the alluvial, with the exception of the humus, but are of much greater thickness. Diluvial gravel is sometimes found forming extensive plains, or constituting hills of small elevation. On the island of New-York, the diluvium occupied all that portion south of Union Square, rising in some places into hills 80 feet in height, and wells have been sunk in it twenty feet, so that its extreme thickness was more than 100 feet. In the valley of the Po and in Provence, the thickness of the diluvium is said to amount to 1500 feet.

81. Among the most remarkable of the phenomena of diluvium are the erratic blocks, or masses of rock rolled by water, which are found mingled with the gravel, or lying scattered on the surface of the ground. These occur singly, but more usually arranged in groups. The instances of erratic blocks which have been most carefully studied, are as follows:

1. The eastern slopes of Jura, a mountain composed of a

calcareous rock, are, as it were, studded to heights of 1500 feet above the valley beneath, with blocks of stone. Some of these are of enormous size, say 40 feet in height and 20 in diameter. They are of the same character with the rocks of the chain of Alps, which bounds the valley of Switzerland on the opposite side.

2. The sandy plains of Northern Germany, Prussia, Poland, and Livonia, from the mouth of the Emms to the Neva, are also studded with erratic blocks. These are of rocks found in place in the Scandinavian mountains. The same is the case in Holstein and Jutland, and similar blocks are found in greater abundance in the southern provinces of Swedeno and in Finland.

3. A great part of the counties of Norfolk and Suffolk, and the summits of the hills of Derbyshire, in England, exhibit erratic blocks like those of Germany; some of these are of rocks found in Westmoreland and Cumberland; but the greater part are more similar to those of the Grampian and Scandinavian mountains.

4. The island of Iceland, which is wholly volcanic, exhibits in many places great blocks of granite.

5. Granite boulders are found on the Andes, at a great distance from any native locality of that rock.

6. At Hyderabad, in India, there are great heaps of granite rocks, also at a great distance from any position where that rock is found in place.

7. On the site of the city of New-York, and on the north side of Long Island, numerous large boulders are found, not only superficial but imbedded in diluvial gravel. The most remarkable of these was twenty feet in length by fifteen in diameter, and was of the same rock with Schooley's Mountain, at a distance of 40 miles in New-Jersey. The passage of such blocks from their original localities is said to have left deep grooves in the formations over which they must have

passed. Such grooves have been observed in England and in the United States.

82. Among the beds of diluvial gravel are some composed almost wholly of shells.

83. There are in many beds of stratified limestone, caverns, some of which are of great extent. These are lined with concretions of carbonate of lime, which, when pendant from the roof, are called stalactites, and when forming a floor, stalagmite. The floor has been broken through in some of these caverns, and after passing through a bed of stalagmite, a mass of diluvial gravel was discovered, in which bones are imbedded; and beneath this a second layer of stalagmite was reached: on penetrating through the latter the original rocky floor was finally discovered.

The most celebrated of these caverns is that of Kirkdale in England, discovered by Dr. Buckland. In this, and resting on the lower layer of stalagmite, were found the bones of hyænas, tigers, wolves, foxes, elephants, rhinocerosses, hippopotami, horses, &c. Of these the skeletons of the hyænas alone were complete, most of the others were gnawed, as by the teeth of the hyæna. It was hence inferred, that before the catastrophe by which the diluvial gravel was formed, this cavern had been inhabited by hyænas, who had dragged in the bones of the animals on which they preyed; that England at that time had a climate suited for animals, which are now only found within or near the tropics; that the whole of these races had been destroyed by the action to which the diluvial gravel was due. By inference from the thickness of the upper bed of stalagmite, it was concluded, that the epoch of this catastrophe was not more distant than 4000 years. There are in England several other caverns of the same description, among which are those of Oreston, Callow, and Banwell.

The caverns of Germany were celebrated before the discovery of those of England. The most remarkable are in the Hartz; at Muggendorf in Bairenth; in Westphalia; and in Carniola.

On the southern slope of the Carpathian mountains, in Hungary, are numerous caverns of the same description.

Several caverns, containing bones, have recently been discovered in France.

But one attempt has been made to explore the caverns of the United States, for bones, namely, by Mr. Featherstonhaugh, in the Helderberg. This attempt was not successful.

84. In some cases, the bones found in caverns are not imbedded in diluvium, but are found aggregated into a pudding stone, by a calcareous cement. Such osseous pudding stones are also found above the surface. Instances of the latter sort are most frequent on the shores and islands of the Mediterranean; among these are Gibraltar, Cette, Aix, Ville Frauche, Antibes, and Nice. They also occur near Pisa, at Cape Palinuro, in Corsica, Sicily, and Sardinia, in Dalmatia, and the island of Cerigo.

It will appear, that the modern chemical formations, and particularly those of carbonate of lime, are mingled with the diluvium, in the case of caverns and osseous pudding stones. Beds of diluvial gravel and sand are also often found cemented by calcareous matter. Among these may be cited the marble, of which the columns of the Representatives' Chamber, at Washington, are built, and which is found at the junction of the Monocasy with the Potomac. Ferruginous and silicious concretions are also found belonging to the same order of formations.

85. In a practical point of view, the most interesting diluvial formations are those in which the gems, gold, platina, and other of the metals are found. These are sands,

gravel, or frequently ferruginous pudding stones. Diamonds have been found only in such formations, and the principal localities are in Brazil, Hindostan, and Borneo; they have also been discovered in North Carolina and Siberia. Diluvial gold is found, although rarely, in Europe; in considerable abundance in Asia on the slope of the Ourals, and near Ekatarinenburgh; and on the western coast of Africa. The richest formations of this description are in Brazil and Columbia. Those of the Carolinas and Georgia are, perhaps, little less so, but are not so profitably worked, in consequence of the high price of labour.

86. No vestiges of man, or of his works, have yet been found in these formations, and, of the other mammalia, probably no living species. Of existing genera, but extinct species, we find—one of elephant; two of Hippopotamus; four of Rhinoceros; one of the horse; two of the tapir; several of the deer tribe; an urus; four species of bears; the fossil hyæna, &c. Of extinct genera are found—the megolonix and megatherium, belonging to the family of sloths; and of extinct families, the mastodon, belonging to the order of pachydermata, and approaching, in structure, to the family of Elephants. Reptiles, birds, and fishes, are rare in these formations.

Of moluscous animals, the genera found in diluvium are all such as at present exist, and the species also appear to be identical.

ORDER IV.—VOLCANIC.

87. Volcanic rocks are still to be seen ejected in a liquid form from openings in the solid crust of the earth; and the inference is unavoidable, that all identical rocks found in similar positions are of like origin. The openings whence

volcanic rocks have been ejected, are cavities at the summit of conoidal mountains, and are called craters.

88. The rocks of decided volcanic origin are:

1. Leucostine, a rock which appears to be a compact felspar, modified by igneous action;

2. Tephrine, a rock of cellular structure, also composed of felspar. Both of these contain crystals of felspar, and of other minerals, and go under the general name of lava;

3. Obsidian;

4. Pumice;

5. Peperine, a conglomerate, in which pyroxene is a constant ingredient;

6. Volcanic Pudding Stone, in which pebbles are aggregated by an igneous cement;

7. Puzzolana, or Volcanic Ashes;

8. Moya, containing charred wood imbedded.

89. The principal minerals disseminated in volcanic rocks are—Felspar, Hornblende, Pyroxene, Olivine, Specular Iron, Mica, Sulphur. There are found imbedded in them, and probably of more remote origin—Quartz, Zircon, Corundum, Spinelle, Idocrase, Garnets, &c.

In some instances, organic remains, and the works of human art, have been found imbedded. The most familiar instances are in the neighbourhood of Vesuvius.

90. There is evidence of volcanic action in rocks, imbedded minerals, streams of lava, and craters in many places where no eruptions have taken place within historic times. There are also instances where volcanic action has suddenly commenced in positions where the most ancient traditions do not reach back to similar phenomena. In no case, however, have eruptions taken place, except where there was distinct evidence of more ancient volcanic action. Volcanoes are therefore classed as extinct or active, and we rank with the former all which have not been in activity for the last three or four centuries.

91. Volcanoes, like mountains, may be arranged in groups. By far the most extensive of these is that which bounds the basin of the great ocean, for an extent equal to half the circumference of the globe. Beginning at the southern extremity of South America, there is evidence of volcanic action in Terra del Fuego and Patagonia; in Chili between 46 and 27 degrees south, there are 20 active volcanoes; in Peru although there is but one, the whole province is subject to earthquakes; in Quito, there are four active volcanoes; in the provinces of Pasto and Popayan, six; in Guatemala and Nicaragua, no less than twenty-one; in Mexico, five; several in California; Mount St. Elias, on the north-west coast, has been seen in a state of eruption. We next find volcanoes in the peninsula of Alaska, and the line of action extends through the Aleutian Islands to Kamschatka, in which here are seven active volcanoes; it then turns to the south, and passes through the Kurile Islands to Jesso and Japan. Between Japan and the Philippines are numerous small volcanic islands. In Luzonia, are three active volcanoes, and the line is produced in a southern direction to the Moluccas. Here it meets a transverse line of volcanic action running east and west. Following it in the latter direction, it may be traced to the western extremity of Java; here it turns to the north-west, and extends through Sumatra as far as Barren Island, in the Bay of Bengal. Towards the east the transverse line may be followed through New Guinea, New Britain, and New Ireland.

Another great line of volcanic action appears to diverge from the former in Kamschatka. At any rate, there is evidence of the existence of volcanoes in Chinese Tartary, and they seem to be in communication with the volcanic country on the shores of the Caspian. The Grecian Archipelago exhibits traces of volcanic action, and volcanic islands are still occasionally raised from the sea. Syria and Palestine, and particularly the neighbourhood of the Dead Sea, show many traces of volcanic action. Active volcanoes have been seen within historic times in the Morea; the volcanic character of Naples and Sicily is well known; and although no active volcanoes are now found in Spain and Portugal, volcanic rocks and minerals abound, and earthquakes are occasionally felt. The line which passes through the last named regions, strikes the Azores, which are of volcanic origin. Besides these great volcanic systems we may mention the volcanic groups of the Canaries and Madeira, and the volcanic island of Iceland.

Volcanic action is, however, most active in changing the face of the globe in the tropical regions of Polynesia. The numerous archipelagos which here exist may be ascribed to the joint action of volcanic fire and the coralline animals, and the islands are to be seen in every stage of formation, from dates as old as the diluvium, or, perhaps, as ths most recent of the ancient formations, until we find them rising from the sea before the eyes of the existing generation.

II. ANCIENT FORMATIONS.

Stratified.

I.—SUPERIOR ORDER.

Supercretaceous Groupe, Delabeche; *Terraines Yzemeniens Thalassiques*, Brogniart. *Tertiary Formations.*

92. The formations of this order have been but lately known to geologists. From the general looseness of their aggregation, except when in the form of calcareous concretions, they were supposed to be of modern origin, and from the low level at which those first studied were found, they were considered as merely alluvial. These views were, for a time, supported by the analogy of their organic remains to those at present living, but more close study showed, that

this analogy was not identity, and it is to the study of their fossils, by Brogniart and Smith, that we are indebted, principally, for becoming acquainted with their true nature.

93. The formations of the superior order occur generally in basins, one side of which is at present open towards the sea, and even where the basin form is not obvious, as in the strata which lie on the two slopes of the Apennines, it may be inferred from other circumstances.

94. This order is easily distinguished by its organic remains, which differ totally from those of the supermedial and lower orders, while its more regular stratification, and the inclined position of its layers, mark its difference from the formations of the modern period.

95. The superior order may be divided into three groups, which are styled Pliocene, Miocene, and Eocene. These are distinguished by the characters of the shells of mollusca, which they contain imbedded. In the pliocene formations, a large proportion of the shells, say more than half, belong to existing species. In the miocene, the proportion of existing species is less than half, while in the eocene, the number of existing species is small. By far the greater part of the shells in all the three groups belong to genera, either identical or closely analagous to those now living.

96. In the superior order of France and England, many of the species which at present exist, are not now found in the neighbouring seas, but in those of warmer climates, and where the species still exist in the neighbouring seas, the fossil shells are usually larger. This would prove that the climate of those countries was warmer when the superior order was deposited, than at present. This is also confirmed by the vegetable remains, which, although of extinct species, are analagous to those of tropical climates.

97. Each group is composed of two formations, one of which has been deposited from fresh, the other from salt water.

98. Among the organic remains there are found, in the superior order, at least 50 species of terrestrial mammalia, none of which belong to existing species.

The most remarkable of these belong to the order of pachydermata; among these are—the deinotherium, the largest of all terrestrial mammalia, and which, from its analogy to the tapir, probably spent most of its life in the water—several species of the mastodon—the extinct families of palæotherium, anaplotherium, &c. Of birds and reptiles there are several extinct species, belonging to existing genera. Of fish, there are 100 species, many of which belong to extinct genera.

99. The negative characters are, that in these formations there have not been found any species of the families of trilobite, orthocera, productus, inoceramus, catillus, ammonite, or belemnite; nor of vegetables, any calamite, lycopodium, or cycada.

100. The formations of the superior order are generally calcareous, sandy, or marly; they contain no localities of the useful metals, and no mineral veins; even of disseminated metallic sulphurets, none seem to be found, except in the lowest coarse beds. The organic remains are rarely petrified, and, in many cases, but little altered.

101 The minerals of value are—some beds of lignite, which may be used as fuel—the *calcaire grossier* of Paris, which is an excellent building stone—plastic clays, fitted for coarse pottery—gypsum, which is found in regular beds in the Paris basin—septariæ, found in nodules, in the London clay, and used in the manufacture of the hydraulic cement, called Roman.

102. The best known localities of this order are, the basins of London, Paris, and the Isle of Wight, and the subappenine hills. In these basins it never occurs at a high level, and the strata are mostly nearly horizontal. In the

sub-appenine hills, it is found at considerable heights, as it is on the slopes of Ætna ; and instances are quoted where it has been elevated 15,000 feet.

In the United States, it forms a band, nearly parallel to the coast, which may be traced from Long Island to Florida.

103. Rocks of volcanic origin are frequently intercalated among the formations of the superior order, showing that this species of action prevailed at the time of their deposit.

II.—SUPERMEDIAL ORDER.

Cretaceous, *Oolitic*, *and Sand-stone Groupes*, Delabeche ; *Terrains Yzemeniens*, *Pelagiques and Abyssiques*, Brogniart. *Newer secondary formations.*

104, THE Supermedial order may be divided into four groups, three of which take their names from the prevailing rock, viz :—

1. Cretaceous, or Chalk ;
2. Green Sand ;
3. Oolitic ;
4. Triasic.

105. The formations of this order are readily distinguished from those of the Superior ; (1) by their chemical character ; (2) by greater compactness in their mechanical structure, which better entitles them to the name of rocks ; (3) by so marked a difference in their organic remains that they may be ascribed to a different creation ; (4) by a want of conformity in their strata, those of the supermedial being rarely parallel to those of the superior order, and of the two, the former has been most disturbed and changed from its original horizontal position. The mode of occurrence of their organic remains is also a distinctive character. In this order they are mostly petrified, a case of rare occurrence in the

superior formations; and impressions, which are the most usual mode in the lower formations, are rare in these.

The three first groups have more analogy to each other than either of them has to the fourth; they are chiefly of marine origin, and the upper rock of one group frequently alternates with the lower rock of that above it.

106. The cretaceous group is composed of the following rocks:—

(1.) *White Chalk*, in which are imbedded flints often in irregular beds, iron pyrites, and sulphate of strontia. Of the former mineral it is the only geological site.

(2.) *Grey Chalk*, or chalk marl, in which are imbedded nodules of horn stone, either dispersed, or in irregular beds, and a rock called fire stone by the English, the *Macigno crayeux* of Brogniart. The latter is a mixture of sand, chalk, and mica.

(3.) *Green Chalk*, which derives its colour from particles of green sand, disseminated through it. This rock contains, imbedded, horn stone, the phosphates of chalk and iron, and pyrites.

(4.) *A Marly Clay.*

107. No remains of terrestrial mammalia have been found in this group.

Of birds, there are several extinct species.

Of reptiles, crocodiles, other sauri, and chelonia, all of species and many of genera, no longer living.

Fish are numerous, and particularly the teeth of sharks.

Of shells, the families belemnite and ammonite, neither of which is found in modern formations, or those of the superior order, make their first appearance here, with the catillus and inoceramus. On the other hand, trilobites, orthoceræ, and producti, do not occur.

Of radiated animals, echini and asteriæ, are numerous.

Of vegetables, confervæ and algæ, are found.

108. The chalk formation occupies a considerable portion of the surface of Europe. It preponderates in the South of England and North of France, and the basins of London, Paris, and the Isle of Wight, rest upon it. From France this formation extends through Belgium into the North of Germany, and thence through Poland into Russia, where it has been traced as far as the Don. Chalk also occupies the South of Sweden, and it appears probable that all the localities we have yet mentioned, form a single basin, on which the modern and superior formations of the shores of the Baltic rest. A distinct chalk formation exists in the North of Ireland, another in Italy, and a third in Spain. Detached formations are found at high levels among the Alps, and on the Pyrenees, rising to 9000 feet.

With this exception, the chalk is rarely found at elevations of more than 600 feet.

Chalk is unknown in the United States.

109 The green sand group may be divided into four distinct formations :—

(1.) *Green Sand.* This owes its colour to a chloritous silicate of iron; it contains, imbedded, much pyrites, but is poor in other minerals. It is interspersed with beds of lignite, in which is found a substance analogous to amber.

(2.) *A Plastic Clay*, containing no carbonate of lime. This is called Weald clay by the English, and is infusible in a kiln. It contains no fossils, except fresh water shells. The imbedded minerals are, cale-spar, selenite, and pyrites.

(3.) *Iron Sand.* This is either sand stone, or conglomerate, cemented by oxide of iron. It lies in beds alternating with loam, clay, marl, and fuller's earth. Its mineral contents also lie in seams, and are hydrated oxide of iron, fossil wood, and brown coal.

(4.) *Anargillaceous Carbonate of Lime*, called Purbeck marble by the English.

110. The fossils of this group bear a strong general resemblance to those of the chalk; that which is distinctive is the genus gryphæa, (molluscous,) which does not appear to occur in the chalk, and is here abundant.

111. The green sand formation comes out from beneath the chalk, in many parts of Europe. In the United States, it forms a belt, on which the superior order rests, extending from Sandy Hook to Georgia.

112. The oolitic group, according to Coneybeare and Philips, may be divided into three series, each of which is composed of three distinct formations, viz. an oolitic rock, a calcareous sand-stone, and a marl. The oolites are distinguished as upper, middle, and lower. The marls are called in England, the Kimmeridge and Oxford clays, and Lias. The latter is an indurated marl, varying in colour from light gray to black. It may be used to form an hydraulic cement, and in lithography. It is remarkable as the principal site of the remains of extinct families of sauri, which differ materially from those which now exist.

113. No more than a single family of terrestrial mammalia has been found in this group, namely, one belonging to the order marsupia. In other respects, the fossils approach in character to those of the chalk, but are of different species, and even those of the different series are not identical. The family of belemnites, however, becomes more rare, and that of ammonites more abundant. Of the extinct sauri found in this group, and especially in the lias, the most remarkable genera are:

(1.) The megalosaurus, an animal uniting the stature of an elephant to the proportions of a lizard, some of whose skeletons have been found 70 feet in length. The organization of this animal would have enabled it to move on the land, but its size must have confined it almost wholly to the water.

(2.) The Icthyosaurus, having four paddles, resembling in position the legs of a lizard, with vertebræ similar to those of a fish.

(3.) The Plesiosaurus, having a body shaped like that of the tortoise. To this body is adapted a neck like that of the swan, which contains a greater number of vertebræ than that of any other animal, either extinct or living.

(4.) The Iguanodon, so called because its teeth have the same structure as those of the living genus Iguana.

(5.) The Pterodactylus, a saurian, in which the limbs were made to move wings, exactly as those of the existing genus of bat; exhibiting the remarkable fact of an adaptation to a similar mode of life, in animals situated almost at the extreme of the grand division of vertebratæ.

114. A few mineral veins are found in this group, which is the highest in which they make their appearance; they do not, however, contain any of the useful metals. Hydrated oxide of iron, manganese, and pyrites are found in the joints of the strata.

115. The strata of the oolitic group are, with the exception of those of the lias, conformable with each other, but unconformable with the chalk. The lias appears not only to have been deposited, but to have been much disturbed, before the lower oolite began to be deposited. In some instances, horizontal strata of oolite are found resting on the edges of strata of lias, inclined at an angle of 45°. The extent of the lias also appears to be much greater than that of the oolites. For these reasons, Brogniart classes the lias with the succeeding group.

The true oolites pass into freestones, which contain sand disseminated through them. These furnish some of the most valuable building stones. Some of these have the invaluable property of being soft when taken from the quarry, and hardening when exposed to the air. Among these may be mentioned the Portland and Bath freestones.

Fullers' earth occurs in regular beds, in the lower oolitic series.

116. The oolitic group occupies a considerable portion of Europe. It has been best studied in England, and in the Jura Mountains, from the last of which the French geologists have named it. It is wholly wanting in the United States, or at least has not yet been discovered; the rocks of oolitic structure found in this country belonging to a more ancient formation.

117. The succeeding group, which with Omalius we shall call Triasic, is named by the English, and some of the German mineralogists new red sand-stone. It is generally made up of the following rocks:

Psammite, a rock composed of quartz, held by an argillaceous cement. The cement is in this group charged with oxide of iron, which gives it a red colour. The quartz may be of any colour, but is often ferruginous.

Red marl, or as it is called in Jersey, red shale;

Bituminous, and carboniferous shales;

Conglomerate, composed of pebbles of quartz, felspar, and rounded fragments of older rocks, cemented by a red clay;

Red clay;

A sand-stone composed of aggregated fragments of quartz, probably occurs in the group, but is rare;

Gypsum;

Rock salt;

Manganesian lime-stone.

118. The upper strata of marl and sand-stone often alternate with the lower strata of lias, and thus there is no decided line of division between the two groups. The gypsum, and particularly the rock salt, are of value; and, in addition, there are subordinate beds of lignite, hydrated oxide, and carbonate of iron, the sulphates of strontia and baryta, and manganese. The lignite is accompanied with fine impressions of fossil vegetables. In the magnesian limestone are found metallic veins, whose gangue is usually the sulphate of

baryta, and which yield cobalt, bismuth, copper, and carbonate of iron. There are also found irregular deposits of calamine and galena. The bituminous shale of this group contains sulphuret of mercury.

119. Besides the rocks we have cited, there is a district of France in which the upper and lower beds of marl and sandstone are separated by a formation of limestone. This is extremely rich in the remains of molluscæ, and has in consequence been called *conchylien.* The other rocks of the group are comparatively barren in the indications of organized life, with the exception of the bituminous shale, which often abounds in the impressions of fishes. It has been generally stated, although incorrectly, that this is the lowest group in which any remains of vertebrated animals are found. The magnesian limestone is the highest rock in which metallic veins are found.

120. The fossils of this group are characteristic, but are so rare in many of its rocks, that it is often difficult to distinguish them from an older formation, similar in its mechanical and mineralogical structure. The new red sand-stone of Connecticut exhibits tracks of the feet of gigantic birds.

121. This formation is among the most extensive in Europe, and is the site of the salt mines of Cheshire and Poland, and of the mercury of Idria. In this country, it is recognized in Connecticut, and is the probable seat of the salt springs and gypsum of the western part of the state of New-York. It seems to be yet undecided whether the very extensive formation of red shale sand-stone and conglomerate which exists in New-Jersey, belong to this, or a more ancient group. If, however, we may form a judgment from the tradition of vegetable remains found many years since at Nyack and at Newark, these rocks are of the new red sand-stone. The red marls in New-Jersey contain sulphuret of copper, and copper pyrites, which appear to take their place as stratified rocks, or to be intercalated in the joints.

122. True coal makes its first appearance in the joints of this group; but the layers are so thin as not to be worth working.

III. MEDIAL ORDER.

Carboniferous group, Delabeche; *Terrains Abyssiques Rudimentaires, Houiller, Carboniferes*, Brogniart; *Lower Secondary Formations.*

123. The medial order is made up of four series:

1. *Millstone grit and shale;*
2. *The coal measures;*
3. *Carboniferous limestone;*
4. *Carboniferous sand-stone.*

124. The rock called millstone grit is composed of angular fragments of quartz and felspar, held together by a hard argillaceous cement. The shale is distinguished from clay-slate by being an aggregate of minute particles, instead of being wholly made up of a single mineral species. These two rocks alternate with each other without any determinate order. The position of this group may be either above or below the coal measures. Although no doubt can exist of its stratification, this mode of formation is sometimes difficult to detect, in consequence of the thickness of the beds of grit, and its resemblance to some of the rocks not stratified.

125. This group rarely contains organic remains. The few which have been found in it are vegetable, similar to those of the coal measures.

126. It is sometimes very rich in metallic ores, which occur in detached spots, in nodules, in druses, and in intercalated beds, but never in veins. These ores are galena, blende, pyrites, carbonate of copper, sulphuret of mercury, specular iron, calamine, manganese, and chrome. With them are

found phosphate of lime, fluor spar, and sulphate of baryta. These minerals are confined to the millstone grit.

127. The coal measures are composed of regularly stratified rocks, the most important of which are :

1. White or gray sand-stone ;
2. Psammite, of white or gray colour ;
3. Psammitic conglomerate ;
4. Shale, often bituminous ;
5. Shaley clay ;
6. Coal, bituminous and anthracite ;
7. Iron stone, an argillaceous carbonate of iron.

In addition, the millstone grit often alternates with the coal measures, as does the limestone of the succeeding group.

128. The coal measures sometimes overlie the millstone grit and shale, and sometimes alternate with the carboniferous limestone ; hence their formation may be of any date between the triasic, and the old red sand-stone. True coal is also found in both the last-named groups, but never as yet of sufficient thickness to be worthy of pursuit.

129. Coal occurs in regular strata, co-extensive with the other rocks of the formation, and with them appears to have been deposited in basins of an extent less than any of the formations of the supermedial order. Each basin, or coal field, contains many beds of coal, which are separated from each other by strata, often numerous, of the other rocks. These beds vary from many feet in thickness, to mere seams. One bed in the coal field of Liege is 60 feet thick, another in Scotland 56. A thickness of 6 or 8 feet is most convenient for working ; and it will not defray the expense of mining, if less than 18 inches.

130. Coal affords distinct evidence of vegetable origin, in fossil charcoal, and vegetable impressions. The organic remains of the group are numerous, and almost wholly vegetable. The few animal remains are the shells of fresh water molluscæ.

The vegetables belong principally to the orders of vascular, cryptogamia, and monocotyledons; and those of the first are most numerous. Among them, are 14 of the family of equisetæ, 130 of that of ferns, 68 of that of lycopodium. Of the monocotyledons are a few palms and grasses.

This enumeration shows, that the flora of the epoch of the coal formations must have differed in a remarkable manne from that of the present day. Those vegetable families which are now most numerous, being wholly wanting; and those which are now rare, numerous. Another remarkable fact is ascertained by the examination of these remains namely, that vegetables belonging to families which are now mere herbs, attained at this epoch to the dimensions of the largest trees. The most striking instance of this is to be found among the ferns, which only in one instance attain the character of a tree at the present day. This tree form is only found, and even then of but small size, in the warmest tropical climates. It may be hence inferred, that the climate of the surface of the earth was extremely hot at the epoch of the coal formations. It also seems to have been uniform over the whole surface of the sphere. At the present day, each latitude, and every different degree of elevation, has its own series of plants; and those of the two continents differ from each other. But the fossil remains in the coal of Pennsylvania and England, of New Holland and Greenland, of India and Melville Island, are identical with each other.

131. The coal of this formation may be of every quality, from an anthracite, containing little or no hydrogen, to that which is richest in bitumen. The same stratum often contains both anthracite and bituminous coal, the former where it lies near the surface of the earth, or is traversed by dykes of trap. It would therefore appear, as we shall illustrate hereafter, that heat had an agency in the formation of coal and that the volatile matter had escaped, wherever the superincumbent strata were not sufficient to confine it.

132. Next to the coal, the most valuable rock of the coal formation is the iron-stone, an argillaceous carbonate of iron, having a lithoid structure, and which occasionally contains carbonate of lime. This is wholly wanting in some coal fields, as in those of Newcastle and Lancashire, but is abundant in those of Liege, Staffordshire, and South Wales. When it does occur in a coal field, and limestone either belongs to the formation, or can be obtained in the vicinity, it is among the richest sources of wealth.

133. The only metallic veins which exist in this group appear to be of galena, which, in the field of Newcastle, is traced from the carboniferous limestone, through the coal measures, into the millstone grit. This galena is accompanied by blende. Calc and bitter spar, sulphate of baryta and quartz, also occur in veins. Iron pyrites is very abundant in this formation, occurring in the coal sometimes in such quantities as materially to injure its quality. Many coal fields are traversed by great dykes, which divide them, as it were into chambers, and which are accompanied by faults.

134. The basins of the coal formation rest not only on carboniferous limestone, but on the carboniferous sand-stone, and on rocks of the submedial and inferior orders. On the other hand, true coal is never found above the triasic group in the formations of the supermedial and superior order.

135. The carboniferous limestone is usually compact, but occasionally granular or lamellar. It contains imbedded crystals of calc spar, and sometimes passes into magnesian and argillaceous carbonates of lime. We have seen that it alternates with the lower beds of the coal measures; it also alternates with the upper beds of the surrounding group. Beds of marl frequently occupy its joints, and it contains caverns, sometimes of great extent.

The colour of the limestone passes from white through all the shades of gray, to black. It is also coloured and variegated by metallic oxides, and thus yields many of the most valuable marbles. When argillaceous, it forms an excellent hydraulic cement. Its organic remains are often petrifactions of white carbonate of lime, which exhibit a beautiful appearance when the mass is polished.

136. The mineralogical character of the carboniferous limestone is so similar to that of the limestone of the submedial order, that in hand specimens they are frequently mistaken for each other. Hence, writers on geology have often confounded them; and the organic remains of the one have been described as belonging to the other. Certain differences, however, are apparent, and others will probably be detected. The family of belemnite, which prevails in the formations of the supermedial order, is wholly wanting in the carboniferous limestone. The family of ammonite is found in the carboniferous limestone, but is wholly wanting in the submedial order, and so we are inclined to believe, in opposition to high authority, are orthoceræ, and the whole crustaceous family of trilobites. The most abundant family among the fossils is the encrinite; but this, except on a close examination of the species, is far from being distinctive.

137. The carboniferous limestone of Great Britain rises to the height of mountains, and is sometimes named from that circumstance. It is every where traversed by numerous veins, and these are often rich in the metals. Lead, in all its varieties, sulphuret and carbonate of copper, antimony, zinc, iron pyrites, and hydrated oxide of iron are found in this formation. These veins also contain many other valuable or interesting minerals, as calc spar, arragonite, pearl brown and fluor spars, selenite, carbonate and sulphate of baryta, sulphate of strontia. Bitumen is also found, and it is the only locality of the elastic variety of that substance.

138. This formation occupies a vast extent in the United States. Mr. Featherstonhaugh in his late tour, first struck

it at Sandusky, and did not lose sight of it on the eastern side of the Mississippi. To the north, it extends to Michilimacinac, and far to the south in Kentucky. In this great formation are situated the lead mines of Illinois and Missouri. On the eastern side of the Allegany ridge, it is comparatively rare. I however found it in its true position in relation to the coal measures, at Cumberland, in Maryland, and forming a parallel mountain range, known from its rounded peaks, under the name of Knobley. It is also found at Ticonderoga, in the state of New-York.

139. The carboniferous, usually called the old red sand-stone group, derives the latter name from a rock strongly resembling the true sand-stone of the triasic group. This rock is evidently of mechanical origin, and is composed principally of quartz, which is mingled with mica and felspar. It also contains fragments of the rocks of the submedial and inferior order, and thus runs into a conglomerate. The mode of union, however, appears to be rather by aggregatian than by a cement. If the red sand-stone formation of New-Jersey do not belong to this group, but to the triasic, red shale is not one of its rocks. Its lower beds pass into grauwacké, a rock which differs from conglomerate, in being made up of angular fragments, held together by aggregation.

140. The upper beds of the carboniferous sand-stone alternate with the lower beds of the foregoing limestone; and its lower beds with the upper beds of the limestone of the submedial group. The layers of sandstone are often divided by beds of clay, either soft or indurated.

141. Organic remains are very rare in this group, being wholly wanting in its upper beds, but appearing in the granwacké. In this country, thin seams of coal occur frequently in this formation, and vegetable impressions may therefore be looked for.

142. The red sand-stone of this group is very barren of

metals, but in some countries the grauwacké is rich in them, as, for instance, in Hungary, where it is traversed by veins containing gold.

143. This group covers a large extent of country in the United States. We have observed it first in the state of New-York, in a narrow ridge, through which the Mohawk makes its way at the Little Falls, and which we have cited as a prolongation of the main chain of the Allegany. A few miles south of this, it meets the western bend of the Catskills, and the formation spreads out to a breadth of 200 miles, between the Pine Orchard and Lake Canandaigua. The south-eastern limit is the Shawangunk mountains, and the blue ridge of Pennsylvania, parallel with which it extends to Georgia and Tennessee, in a broad belt, forming the loftiest summits of the Allegany. Of all these ridges it constitutes the eastern face, and dips with more or less rapidity to the N. W., being in some cases almost vertical. On the western slope of many of the ridges, the anthracite coal formation is to be found, resting immediately on the red sand-stone. This anthracite is, therefore, in the lowest position of the coal measures, and is, in some places, said to be evidently beneath the carboniferous limestone; but those who consider the anthracite of Pennsylvania to belong to the submedial order, err.

IV. SUBMEDIAL ORDER.

Terrains Hemylysiens, Brogniart; *Grauwacké and lower fossiliferous groups*, Delabeche; *Transition Formations.*

144. The passage from the former order into the submedial, is by no means marked; and thus the grauwacké which we have ranked with the former, might with equal convenience be placed here. Omitting it, this order may be divided into two groups, transition limestone and slate.

145. The transition limestone resembles in chemical and external characters, the carboniferous. So far as we have been able to judge, it is more frequently crystalline in its structure. It is generally of a dark gray colour, and sometimes quite black. This colour arises from carbon and bitumen disseminated throughout the mass. The pure limestone often passes into one containing carbonate of magnesia, or much silicate of alumina.

146. The transition limestone of the United States contains numerous nodules of hornstone. It does not appear to be rich in metals, although some copper mines have recently been found in this formation in Virginia. Brogniart calls it rich in the useful metals, but he appears to confound it with the carboniferous limestone.

147. The organic remains of this group are very numerous. Of vertebrated animals, no others occur except a few fish. The molluscæ are principally, if not wholly, chambered on multilocular. Of these, the ammonite is wholly wanting, and is replaced by the orthocera. Of chambered bivalves the productus is the most remarkable, but is said to be also found in the carboniferous groups. Among articulated animals is found the family of trilobites, which was probably crustaceous, and of these the calymene of Blumenbach is decidedly characteristic. The discovery of this by myself at Trenton Falls, identified the great limestone formation of the Apalachian group of mountains with that of Dudley, and, in consequence, with the transition rocks of Europe. From the same place was brought a new and remarkable trilobite, which was described by Dr. Dekay under the name of isotelus.

Of radiated animals, the family of encrinites is extremely abundant, and the rocks of Trenton Falls containing coralliform crystallizations. The same are found in Europe. As the molluscous families of nautilus and terebratula also occur, we have in them instances of three families which pass through every formation, from those of the present day to the most ancient.

A few vegetable remains have also been found, either cryptogamous or monocotyledonous.

148. The transition limestone occupies a narrow belt of very great length in the United States. In North Carolina, Virginia, Maryland, Pennsylvania, and New-Jersey, it lies in a valley, often diversified by hills of moderate elevation, between the first and second ridges of the Apalachian group. It enters the state of New-York in Orange County, and follows for a time the course of the Wallkill. Thence it passes toward the Hudson River, at Newburgh, where it is covered by diluvial gravel, but re-appears at the surface on the eastern bank at Fishkill. From thence to Rhinebeck it is wholly confined to the eastern side of the Hudson; here it again crosses the river, and spreads to a considerable width in the neighbourhoods of Kingston and Catskill. At Hudson it occupies both banks of the river, and extends eastward for several miles, but here finally crosses the river. North of Kingston it changes its level, and begins to rise to a mounstain height, forming the Indian ridge, which, although small when compared with the neighbouring Catskills, equal the Highlands in elevation. This ridge is produced into the Helderberg, which passes to the north-west through Albany and Schoharie counties. In the latter it forms a rich valley, and rising again encloses the valley of the Mohawk on both sides, and often with precipitous cliffs. At the Little Falls of the Mohawk it is covered by the formation of red sandstone and grauwacké, but it is speedily seen again, forming the valley of West Canada Creek, and then rises into a table-land, whose southern slope presents the aspect of a mountain ridge. In

issuing from this ridge Canada Creek forms Trenton Falls, and the formation is opened to a great depth. To the north of Trenton the formation extends to a great breadth, and may be traced to the north-west across the St. Lawrence, and into Canada.

On the eastern side of the Highlands it is occasionally found in small formations, which appear to have been divided when that range was elevated, and it is found in detached masses on its eastern slope. The red sandstone of the valleys of the Passaic and Hackensack, are often covered with boulders of the transition limestone.

149. The slate group is composed of the following rocks:

Clay slate;
Roofing slate;
Silicious slate;
Talcose slate;
Calcareous slate;
Chlorite slate;
Micaceous slate.

Its upper layers alternate with the transition limestone, and it is to be distinguished from the inferior order in many cases, only by its rocks either containing fossils, or alternating with such as do. It is the lowest group in which any trace is to be found of organized beings.

150. The organic remains of this group appear to be similar, if not identical, with those of the transition limestone. Although its stratification is distinctly marked, the formation by crystallization begins to play an important part. This is apparent in the great number of imbedded crystals. Its stratification is much disturbed, being frequently twisted and undulating. It abounds in veins, and is among the formations most rich in the metals.

V. INFERIOR ORDER.

151. The inferior order is composed of two groups—that in which the slatey structure predominates, and that in which, although still stratified, the formation by crystallization is the most obvious character. Among the slatey rocks, no others need be cited than those enumerated in the last group of the foregoing order.

The crystaline stratified rocks are:

Gneiss, a rock composed of felspar, mica, and quartz, and therefore identical in composition with granite, from which it differs by its stratified formation;

Hyalomicte, which differs from gneiss, in wanting the felspar;

Mica slate, which contains but little quartz, and is sometimes wholly composed of mica;

Eurite, wholly composed of compact or granular felspar;

Hornblende slate;

Quartz slate;

Siderocrist, made up of specular oxide of iron and mica;

Magnetic oxide of Iron;

Granular Carbonate of Lime, from the coarsest grains, whence perfect crystals may be separated, to saccharoid;

Granular dolomite;

Protogine, a rock composed of talc and felspar.

The siderocrist often contains native gold in small particles, and has been suspected to be the original site of the diamond.

Pyrites is often imbedded in the rocks of this formation, and sometimes forms one of its rocks. In the latter case it is occasionally rich in gold.

In the upper strata of this formation the slatey rocks predominate, and in the lower gneiss; the others occur in no determinate order.

152. No single stratum of the lower rocks of this order, has ever been pursued to any great distance, nor do they occur, as in the higher orders, in any determinate manner. It may hence be surmised, that so far from each stratum being coextensive in formation, it has a form that may be likened to flat plates, which, however extended, finally run out.

The stratification of this order is not only wanting in regularity of succession in different places, but is more frequently contorted and twisted from its original position than any other. In some cases a section of the rocks exhibits the joints in waving or even zigzag lines. This disturbance extends so far that the order of the series appears inverted, the rocks having been raised beyond the vertical position, and, as it were, overturned.

153. These disturbances may be explained by reference to the action which has penetrated the whole order by innumerable veins, which are often the seat of valuable ores. Metallic minerals are also disseminated. Among those found in either mode are:

Magnetic iron;
Specular iron;
Iron pyrites;
Arsenical pyrites;
Copper pyrites;
Sulphuret of copper;
Native copper;
Native gold;
Molybdena;
Galena;
Argentiferous Galena;
Blende;
Chromate of iron;
Gray cobalt;
Sphene;
Titaniferous iron;
Columbium;
Oxide of tin.

Anthracite is found in the clay slate, and graphite in the lower rocks.

The earthy minerals found either in veins or imbedded, are also numerous. Among them are:

In the slate, Macle, Staurotide, Dipyre. In the other rocks:

Quartz;
Garnets;
Sahlite;
Epidote;
Tremolite;
Idocrase;
Hypersthene;
Zircon;
Spinelle;
Wernerite;
Pyroxene;
Idocrase;
Actinolite;
Tourmaline;
Beryl;
Gadolinite;

154. This order occupies a large surface in the U. States. Forming the White and Green Mountains, it may be traced along the outer or Atlantic ridge of the Apalachian group to the state of Georgia. From this ridge innumerable others, of small height, proceed in a southerly direction, dividing the space between that ridge and the green sand formation into separate basins. One of these ridges leaves the highlands, on the east bank of the Hudson, and terminates at the Battery. Between the latter point and Union Square it is covered with diluvium. Another extends through Jersey to Trenton, where it forms the falls of the Delaware. A third follows the western bank of the Schuylkill, and strikes the bank of the Delaware near Wilmington. A fourth is to be seen west of Baltimore, at Ellicot's mills. Many others might be cited. It is to the decomposition of the rocks of this formation in which quartz abounds, that we are to ascribe the sandy pine barrens of North and South Carolina. When hornblende predominates, the surface is covered with the red clay so abundant in Virginia and North Corolina, although these soils may also be derived from granitoid rocks.

155. The granular limestones and dolomites of this formation furnish the most beautiful material for architecture in the greatest abundance. Among the localities may be mentioned those of Kingsbridge, Sparta, and Eastchester. From the latter were quarried the splendid pillars of the late Exchange, and the obelisk erected to the memory of Emmett, in single blocks between 30 and 40 feet in length. It is said that pieces of 100 feet in length might be readily extracted from the same quarry. The neighbourhood of Philadelphia furnishes similar marbles, but the quarry seems to have been exhausted, as the blocks recently extracted are veined and incline to a gray colour. A still more beautiful variety is found at Stockbridge, in Massachusetts, some of which is of so fine a grain as to rival the Parian. The firmer layers of these rocks, when free from pyrites, seem to be almost indestructible by the weather.

The gneiss is valuable as a rude building and paving stone, and with the gneisiform rocks is often worked as a building stone under the name of granite. This, although harder, is rarely as durable as the white marble, for the felspar it contains is liable to decomposition, and causes the rock to desquamate.

156. The crystaline rocks of the inferior order have been found beneath every other formation, from those ef the modern epoch to the slates; and although in many cases the thickness of superinposed formations is such as to prevent their being penetrated, it has been inferred, that these crystaline rocks envelop the whole globe, and serve as the basis of all the other formations. Beneath the gneiss no other rock has been found, except such as are granitoid, and it is by no means clear that even rocks of this description are always inferior to it in position.

157. In referring back to the descriptions of the several stratified formations, it will be seen that no more than three can be considered as enveloping, or equally extensive with the surface of the continents. These are: the humus, the diluvium, and the lowest rocks of the inferior order. The first of these may rest directly on the second, or the beds which we have described as alluvial may be interposed. So also, as in the island of New-York, the diluvium may rest directly on the gneiss; upon the highest formations of the superior order; or upon any of the intermediate series. Of the several formations, little or no doubt can exist that the superior order, and the coal measures, have been formed in basins of no great extent. There is also strong probability that all the other formations, down to the slate of the inferior order, have likewise been deposited in basins of greater magnitude, and that these greater basins have not always included the lesser ones within their limits. The strongest proof of this lies in the fact, that whole groups, series, and orders are often wanting in places situated in countries where these very formations exist at no great distance; and there are countries in which particular formations do not occur at all. It might therefore appear at first to be liable to doubt, whether the order in which we have ranked them is absolutely correct, or whether some which are described as different in position may not be identical in age. No doubt, however need remain, when the circumstances are fully investigated.

(1.) By examining the strata at their outcrop on the general surface, on the edges of deep ravines, or on the faces of precipitous mountains; by sinking wells and the shafts of mines, the order of superposition of many of the formations has been thoroughly determined.

(2.) Although in places, or even in large districts, whole formations, groups, or even orders, may be wanting, it has never been observed that a stratified rock has been found resting upon one that belongs to a higher place in the system we have given.

(3.) In some countries almost every formation which we have classed in the five orders, has been found in the very position assigned to it. The best known instance is in England, where, if a traveller set out from the mountains of Cumberland, he may pursue such a line in travelling south-eastwards to the British channel, as will carry him over the outcrop of every one of the five orders, and over every individual formation, except the conchitic limestone of the triasic group.

These orders, with their groups and series, will be found to occur superinposed in the manner which has been set forth.

It yet remains to be ascertained, whether some countries, when explored, may not exhibit rocks and formations unknown in those countries where geology has been best studied.

(4.) Every one of the four first orders abounds in organic remains, and these are found to differ from each other, not only in species and genera, but in families. In some cases, even in formations in immediate contact, this difference is so great as to make it appear as if all the animal life which had existed during the deposit of the lower order, had been destroyed, and replaced by a new creation. In proceeding downwards, we find that the mammalia gradually disappear, none except the marsupia reaching as low as the supermedial order, where even that family is extremely rare; and in the lowest formations, all vertebrated animals, except fish, cease to be found. The latter, of all animals, furnishes the strongest proof of the succession of the stratified rocks, which has yet been adduced. The researches of Agassiz have shown that the character of fossil fishes does not change by insensible degrees from one formation to another, as is frequently the case with molluscous and radiated animals, but is always abrupt. Among all the fossil fish he did not find one which was common to two great geological formations, or which existed at the present day.

158. From these considerations, the inference is certain that the several formations, from the slates upwards, have been deposited in succession, beginning with the inferior order, the epoch of whose deposit is most remote; that, when two formations are found identical in their organic remains, however remote from each other on the surface of the earth, they belong to the same epoch of the earth's geological history; and that, where formations are wanting in any place, it is because it was beyond the reach of causes then in action on other parts of the globe, or because they may have been since removed by some geological cause.

159. It is therefore obvious, that the thickness of the several formations which we have described, will be an important element in the investigations to which the third division of our subject is devoted. These thicknesses, as given by the most recent authorities, are as follows:

		FEET.	
Superior order.	Pliocene,	80	
	Miocene,	100	
	Eocene,	600	
			780
Supermedial order.	Chalk,	700	
	Green Sand,	500	
	Iron Sand,	950	
	Upper Ooolite,	770	
	Middle Ooolite,	880	
	Lower Ooolite,	820	
	Triasic,	2100	
			7720
Medial order.	Mill-stone grit,	700	
	Coal measures,	1000	
	Carboniferous limestone,	850	
	Do. sandstone and grauwacké,	10,000	
			12,550
Submedial order.	Transition limestone,	1800	
	Do. slate,	2500	
			4300
			24,350

160. The several thicknesses given above are the average of many observations. It rarely happens, in spite of the rule of conformity which is observed in the strata of the same formation, that a constant thickness is maintained throughout; many of the beds, on the contrary, gradually thin out from a maximum, until they, in some cases, become mere seams. In spite of this, every formation higher than the crystaline rocks of the inferior order, appears to be composed of a regular series of strata, which occur, in any given district, in a constant order of succession, and which, even in the most distant parts of the globe, do not vary materially from that order. The widest deviations from absolute regularity of succession, are found in the Eocene group, and in the coal measures. In the former, the formations of similar date are: in the London basin, a marly clay, and in the Paris basin, the *calcaire grossier.* The coal measures may, as we have seen, be found in any part of the medial order, between the carboniferous sandstone and the lower rocks of the submedial. The rules do not apply to the rocks which remain to be treated of, namely, those not stratified. They are confined to no specific place; each of the orders into which we have divided them, may be found traversing, or even intercalated, in the strata of more than one of the groups, and frequently extending through several orders.

ROCKS NOT STRATIFIED.

ORDER I.—GRANITOID.

161. The type of this order is granite, which is a highly crystaline rock, composed of quartz, felspar, and mica. Each of its constituents may also exist as a rock of the same order. This is not generally admitted in respect to the

mica, but near Easton, Pennsylvania, there is a mica rock, containing imbedded zircon, which has no appearance of stratification. Including these, the rocks of this order are:

1. *Granite ;*
2. *Quartz rock ;*
3. *Felspar rock ;*
4. *Mica rock ;*
5. *Syenite*, composed of quartz, felspar, and hornblende;
6. *Diorite*, or primitive greenstone, composed of felspar and hornblende;
7. *Hornblende rock ;*
8. *Pegmatite* or Graphic granite, composed of felspar and quartz, and which, by its decomposition, forms
9. *Kaolin*, or China clay;
10. *Protogyne*, composed of talc, or stealite and felspar;
11. The rocks 5, 6, and 7, in which hornblende predominates, appear by their composition to form a red clay: we have seen decided instances of this in the gold region of North Carolina.
12. At Salisbury, Conn., there are two veins of granular carbonate of lime, traversing gneiss and mica slate rocks, abounding in garnets and staurotide. It therefore can hardly belong to any other order than this.

162. These rocks all contain numerous imbedded minerals. The most important of these are as follows:

Topaz,
Tourmaline,
Zircon,
Garnets,
Crysoberyl,
Pyroxene,
Hyperstene,
Phosphate of lime,
Petalite,

Quartz,
Spinelle,
Epidote,
Beryl,
Pinite,
Idocrase,
Diallage,
Lepidolite,
Triphane,

Molybdena,
Titanium,
Magnetic oxide of iron,
Wolfram,
Oxide of tin,
Plombago.

163. Granite was at one time considered as the most ancient, as it was thought the lowest in position of all the rocks. This is however far from being the case, and this group is now known to be intercalated among rocks of sedimentary origin.

164. Granitoid rocks occur in masses of various dimensions, from the size of mountains to that of thin veins. They are found beneath gneiss, and intercalated among the gneisiform rocks of the inferior order. They also traverse the inferior order in veins, and have been found in this form as high as the transition limestone. Thus: near the bank of the Delaware, opposite Easton, is an exposed mass of transition limestone, which is traversed and divided into two parts by a granitoid vein. This group has no limit in the descending order, as it often lies beneath gneiss: and we are inclined to consider, as belonging to it, the veins which are found as high as the magnesian limestone.

ORDER II.—PORPHYRITIC.

165. The distinctive rock of this formation is Porphyry, which is a compact felspar, containing crystals of felspar of a different colour, and crystals of quartz. The colour of the felspar paste is sometimes red, and hence the rock derived its name; sometimes gray, or almost black.

166. The rocks of this order differ from those of the preceding in being less decidedly crystaline. They have not been found beneath the gneiss, but they traverse, in the form of dykes, the rocks of the inferior, submedial, and medial orders.

167. Including the type, the rocks of this order are as follows, viz :—

1. *Porphyry ;*

2. *Eurite ;* a compact felspar, containing no crystals.

3. *Melaphyre ;* a rock composed of a mixture of felspar and augite, containing crystals of felspar.

4. *Green-stone Porphyry ;* composed of felspar crystals, imbedded in a paste of felspar and hornblende.

168. With the exception of the characteristic crystals of the porphyry, this order contains but few imbedded minerals.

ORDER III.—TRAPP.

169. The rocks of this order are characterized by a tendency to split into the form of prisms. They may be classed as follows :

1. *Trapp and aphanite ;* composed of felspar and hornblende.

2. *Basalt and dolerite ;* composed of felspar and augite.

3. *Melaphyre ;*

4. *Green-stone Porphyry ;*

5. *Amygdaloid,* trapp or aphanite, containing vesicular cavities, usually filled with crystaline minerals ;

6. *Wacke ;*

7. *Green earth,* arising from the decomposition of the other rocks.

170. These rocks, and particularly the amygdaloids, contain many imbedded minerals, and this forms the main distinction between them and the porphyritic. Among the imbedded minerals are :

Pyroxene, Olivine,

Schorl,
Felspar,
Mesotype, and all the zeolitic minerals,
Prehnite,
Amethyst,
Jasper,
Harmotome,
Calc-spar,
Arragonite,
Chabasie,
Agates,
Opal,
Sulphate of Strontia,
Sulphate of Baryta,
Native copper.

171. The rocks of this order occur principally in dykes, which give birth to intercalated masses; they also occur in overlying masses, aspiring to the dimensions of mountains. They do not occur intercalated in any formations lower than the medial order, and seem to be limited on the other side by the diluvium. The most important rocks of this order are those which traverse, in the form of dykes, many of the coal fields. By these dykes the basins are divided, as it were, into many separate chambers; and were it not for the obstacle which these oppose to the filtration of water, it would have been impossible to have drained many of the masses of that useful fossil.

172. Among the most celebrated formations of this order are those of the Giants' Causeway, in Ireland, and Fingal's Cave, in the Isle of Staffa. In these localities the fissures give to the rock the form of polygonal prisms, and these are often nearly regular in their form. Each pillar is composed of blocks, having a concave and convex surface.

The neighbourhood of New-York furnishes many interesting localities of this group. On the opposite shore of the Hudson is a ridge called the Pallisadoes, composed of columnar trapp. This is first observed beneath the surface of the water at Bergenport, and, gradually rising, reaches the height of 600 feet, at Haverstraw. This ridge is traversed by but a single pass, at Tappan. At Haverstraw the mountain bends and encloses a basin occupied by a lake, and having the aspect of a volcanic crater.

A few miles east of the Pallisadoe ridge are two others, nearly parallel to each other, known by the names of the first and second Newark mountains. The first terminates at Springfield, the second continues to the south towards Boundbrook, then turns west, and bending into the shape of a hook, terminates at Baskenridge. These three ridges are all overlying masses, resting upon sand-stone. The junction of the trapp and sand-stone formations can be well examined in the ravine at Paterson, through which the Passaic river has made its way by taking advantage of a natural fault. A fourth ridge rises near Morristown, and extends six or eight miles to the southwest, and which appears to be a dyke.

Adjacent to the Newark mountains is a basin nearly circular, and about three miles in diameter, enclosed on all sides but one by a ridge of trapp. This, although now filled by a level plain of alluvium, has also much of the aspect of a crater.

In Connecticut there are also many ridges of trapp. Those which I have examined in the vicinity of Hartford differ from those of Jersey, in being dykes.

173. Trapp and Basaltic rocks are not only found in vertical, but also in inclined prisms, and a bed of one of these often rests upon the other. Of this there is also a good instance at Paterson.

174. Rocks of this order are occasionally found in globular masses, forming conical heaps. At Baskenridge, where we have seen that the second Newark mountain terminates, there is a heap of this sort imbedded in green earth. On digging into this heap, it was found that the masses gradually became angular, then truly prismatic, and finally merged in a solid mass of trapp. The inference was obvious, that the globular form had been caused by desquamation.

ORDER IV.—OPHIOLITIC.

175. The rocks of this order are as follows:

1. *Serpentine;*
2. *Ophicalce,* a mixture of serpentine with carbonate of lime, and which, when the former preponderates, and the carbonate occurs in veins, is known as verde antique marble;
3. *Euphotide,* composed of diallage and felspar;
4. *Magnesite,* a silicitate of magnesia;
5. *Granular dolomite.*

176. The serpentine rocks are traversed by many veins, and with the others contain numerous imbedded minerals.—Of those which occur in these different modes the most important are:

Hydrate of magnesia,
Carbonate of do.
Hornblende,
Sahlite,
Oxide of chrome,
Manganese,
Idocrase,
Felspar,
Asbestus,
Crysoprase,
Chromate of iron,
Magnetic iron.

177. The vicinity of New-York presents two interesting localities of this order, at Hoboken, and on Staten Island. It is from observation of these localities that, in opposition to other authorities, it is stated that the serpentine rocks are traversed by many veins. On the island of New-York and on the bank of the Hudson, at Anthony's Nose, serpentine is associated with gneiss and mica slate; the lower limit of this order is therefore the latter rock. Brogniart states that its upper limit is unknown. It probably does not ascend very high; at any rate, the rock of Hoboken is older than the adjacent sand-stone.

ORDER V.—TRACHYTIC.

178. The rocks of the Trachytic order are:

1. *Trachyte*, composed of vitrous felspar;

2. *Domite*, felspar having an earthy aspect;

3. *Argillophyre*, a porphyritic rock, whose paste is a decomposing felspar;

4. *Klinkstone*, a compact rock whose constituents are the same as felspar;

5. *Perlite;* felspar having a pearly lustre, and which is sometimes porphyritic.

179. The distinctive character of these rocks is, that the felspar of which they are composed appears to have been modified by heat.

180. The rocks of this order form mountains, among which are some of the most elevated on the surface of the earth. Among these may be cited Chimborazo. In their general form, and from the traces of craters, these mountains resemble those which are decidedly volcanic.

181. Brogniart fixes the lower limit of this order at the chalk, and it may be traced into the higher formations of the superior order. It thus appears cotemporaneous with the newer trapp and older volcanic formations.

182. This order has not been discovered within the limits of the United States.

183. We might add to the order of ancient unstratified rocks, the volcanic, which has for its lower limit the higher limit of the trapp rocks. These two orders indeed change into each other by insensible degrees, and in the neighbour-

hood of extinct volcanoes the rocks of the trapp order often preponderate. It is by observing what occurs when a stream of lava has entered the sea that we can form a guess at the origin of trapp rocks, for in this case the stream assumes the columnar or basaltiform structure.

III. GEOGENY.

184. We may inquire into the manner in which the crust of the earth has attained its present state, by studying the phenomena which are taking place under our own eyes. In this examination we discover the agency of certain proximate causes, and by a comparison of the formations which are certainly produced by them, with those of more ancient date, we infer from the analogy of structure and character, that the same causes were also in action at more remote epochs of the earth's geological history. We may thus determine to what description of action the several ancient formations were probably due, and we may, in one instance at least, go back a step further, and inquire, whether in the known laws of physical science we can discover the reason of the prevalence of the action of one of these proximate causes. The same physical laws may be applied in the progress of the inquiry, to explain the reason why formations to which the same proximate cause can with certainty be assigned, differ in character from each other; and the spirit of inductive investigation will enable us to reach, by analogy, the agent which was concerned in formations whose origin cannot be otherwise ascertained.

185. We have ranked first among modern formations those which are of a vegetable origin: with these may be classed the coralline shoals and islands, and we thus infer, that the birth, growth, death and decay of organized beings is a cause whose action is to be sought among the ancient formations.

186. Next in order we may cite the mechanical action of water, by which portions of the more elevated parts of the surface of the land are continually torn off, or worn away, and again deposited in the forms of boulders, pebbles, gravel, sand, and mud. In the deltas of great rivers we find these occupying large extents of what was formerly a part of the ocean, and arranged in regular layers. In such formations we find imbedded the remains of animal and vegetable life. The enormous quantity of solid matter continually carried into the ocean by rivers, which far exceeds the alluvium which they add to the extent of the continents, shows us that similar formations must be taking place in the depths of the sea; these must contain all the matter found in deltas, modified by the mechanical action of the sea itself, and charged in addition with the remains of the animals which inhabit the ocean, or bound and aggregated by the labours of the coralline zoophytes.

187. The surface waters of the earth not only exert a mechanical, but also a chemical action. The most extensive formations of this character are composed of carbonate of lime, taken up by water holding an excess of acid, and deposited when that acid escapes. The sulphate of lime, which is soluble without any intermediate agent, is also deposited in the form of carbonate, receiving the necessary acid from the atmosphere. Such calcareous deposits take the form of stalactite, travertine, and tufa; they also convert beds of pebbles, gravel, sand, and clay, into conglomerates, calcareous sandstones, and marl. Silica is also carried in solution by water, and deposited; carbonate of iron is dissolved by excess of acid, and thrown down in the form of hydrated oxide generating beds of bog ore, or applied in cementing deposits of mechanical origin.

In the gradual decay of organized structures, these chemical deposits take the place of the decomposing substances, and, assuming their form, generate petrifactions. The chemical formations also enclose and envelop the organic matter, which gives its impression to them. It may thus be preserved from diminution, but as its elements are combined under an action very different from that of chemical affinity, they gradually enter new combinations, and while the form and structure may remain unchanged, compounds unknown either to the organic or mineral kingdoms are generated. Such compounds also occur when the organized bodies are enclosed only by mechanical deposits.

188. The foregoing phenomena require close investigation in order to estimate their importance. It is not so with those which go by the name of volcanic; these, from their violent, although intermitting action, more powerfully arrest the attention. The most obvious phenomenon of volcanic agency, is the ejection of quantities of earthy matter liquified by heat. These are thrown out of cylindroidal orifices, and running over their edges, raise them, on consolidating by cooling, into the form of conoidal eminences. The succession of such eruptions gives to the mass of the cones a structure closely resembling the stratification produced by deposit from water. From this it differs in the variable extent of the several layers. The matter thus ejected often differs in its chemical character, but a more obvious distinction arises from the varying rate at which the cooling is effected. In contact with the air, or in masses of small thickness, the cooling is sudden, and the rock formed is compact, and of uniform composition; but when the cooling is more gradual, a tendency to crystalization becomes apparent, and finally rocks of unquestionable volcanic origin assume a granitoid structure; the several elements contained in the liquid mass having obeyed their chemical affinities, and the compounds thus formed, arranged themselves according to the laws of crystaline aggregation.

Gases and vapours escaping from the igneous mass, while in the act of consolidation, often leave it full of vesicular cavities; into these, mineral matter is occasionally carried by the filtration of water, and deposited in crystaline forms, or in concentric layers.

The eruptions of volcanoes are often preceded by earthquakes; these rend and tear the rocks of former ejections, which may also have been rent by their own contraction on cooling. The fissures formed in either way are filled up by the matter of subsequent eruptions, in the form of dykes and veins, and these may penetrate into rocks of other origin, and cause them to be traversed by similar joints, or intermixed with intercalated rocks.

Besides a regular flow of liquid matter, over the level edge of a crater, it frequently happens that the edge is not level or has been split into fissures. In such cases, instead of spreading uniformly, and assuming a structure resembling stratification, the lava makes its way in streams; these, on cooling, form overlying masses, and should they enter into the sea, assume the columnar structure which we have observed in the trapp and basaltic rocks.

The earthquakes which precede volcanic eruptions, often raise the ground in which they prevail, and thus when a vent is found, the crater makes its appearance in the middle of a mountain formed of rocks of an origin wholly distinct. Such mounts may not only be formed of land already in the dry state, but may be raised from the depths of the sea. In this way the curious but frequent spectacle is presented, of formations of aqueous origin, overlaid, traversed, and penetrated by volcanic rocks.

The ejections of volcanoes are not limited to matter in a state of igneous fusion. Solid bodies are often thrown out with great violence in the form of fine powder, sand, angular fragments of the size of gravel, or pebbles, and even large blocks. These falling to the ground may be cemented by streams of lava, by the finer particles formed into a paste by the water of rains, or by the condensation of the vapour, which is an usual concomitant of volcanic eruptions.

Aqueous matter not only appears in the form of vapour, but floods of heated water sometimes issue from volcanic craters, or are poured down from the melted snows. There are instances where the matter ejected was mud, and this has been found filled with fish, or charged with matter of vegetable origin.

The action of subterranean heat changes the character of the rocks exposed to it. Clay and marl are indurated, or even vitrified; vegetable and animal matter partially changed, or wholly carbonized. Vapours other than that of water are ejected, and, on cooling, enter into chemical union, forming crystalized minerals, saline or inflammable.

189. We have seen that volcanic ejection may be preceded by the elevation of hills, or even mountains. Earthquakes, even where they are not followed by eruptions, may produce elevations of the land. The most remarkable instance of this kind is to be found on the coast of Chili, where, under the eyes of the existing generation, an extent of many miles of beach was raised 20 feet above its former level. Other beaches were, on examination, found on the same coast, which must have been raised in a similar manner, at former periods. As earthquakes are a phenomenon inseparable from volcanic action, we may assign to the agency of subterranean heat this remarkable phenomenon. With it may be classed, although the connection is obscure, the slow and gradual elevation, which it is now admitted is taking place on the Baltic coast of Sweden.

190. In examining the orders of rocks we have classed as ancient, no doubt can remain that the several species of action which we find in operation at the present day, have been concerned in their formation, either separately or united. Thus: from the higher groups of the superior order to the lower strata of the submedial, we find evidence of the continued presence of organized beings; in the marls and clays of the several orders we note deposits from waters in a quiescent state; in the sandstones and conglomerates, of similar deposits from water in motion; in the calcareous formations, of precipitation from solution, aided by the action of the coralline zoophytes, and mingled with the exuviæ of animals.

In comparing the rocks produced by the action of volcanoes, either active or extinct, with those of the trapp, trachytic and porphyritic orders, we cannot hesitate at ascribing the latter to the same general cause of internal heat; while the transition from the porphyry to the granitoid rocks is so insensible, that we cannot refuse to believe, that the same agency which formed the one, must have been efficient in the creation of the other. Of the unstratified rocks the ophitic group alone falls with difficulty under the general head of igneous origin; but when we consider that carbonate of lime, serpentine, and the magnesian minerals have been fused by artificial means, we need no longer hesitate in ascribing to the same igneous action the rocks of this group, which resemble, in their mode of occurrence, in dykes, veins, and as the nuclei of mountains, those whose origin is unquestionable.

191. Derived from the same general cause, the circumstances under which the several unstratified groups have taken their place in the solid crust of the earth, are by no means identical. The mode of ejection from craters is that which has alone been instrumental in the generation of the volcanic rocks, whether of the ancient or modern period; and this seems to be also true of the trachyte. The trapp rocks have not only been ejected from craters, but have been protruded through fissures and faults, in the form of dykes. The latter method alone is applicable to the porphyritic and ophitic groups, while the modes in which the granite occurs are, in veins, in masses overlying or intercalated with the strata, and as the nuclei of mountains.

192. The crystaline rocks of the inferior order, although approaching to the granitoid in their structure and mineralogical character, are stratified, and hence they are frequently considered as having been deposited from water. It is not necessary, however, to have recourse to this fluid in order to account for their stratification, for we have seen that a similar mode of arrangement is found in the craters of volcanoes, which also exhibit the phenomena of dykes, veins, intercalated and overlying masses, so common in the gneissiform rocks. To these rocks, then, we would also ascribe an igneous origin.

In following the reliques of animal life, from the present day to the lowest formations in which any trace of it exists, the changes which have taken place in the inhabitants of our globe present a curious spectacle. Each different order, group, series, and even many single formations, have their distinctive fossils. Only two genera seem to be common to all, and these differ in species from formation to formation.

The mammalia, even of the diluvium, differ in species, in genus, and often in family, from those of the present day: they are abundant in this and in the strata of the superior order, but cannot be traced any farther, except in the single instance of the family of marsupia.

In the supermedial order, no trace of this class is found, but reptiles are numerous, at first belonging to existing genera, but finally to families very different from those of the present day.

The remains of birds have been traced as low as this order, but fishes are found as long as there is evidence of animal life having existed. These, which belong in the higher rocks to genera now existing, become more and more different from those of the present day, and it is in this class that we now find the most marked evidence of the changes in the inhabitants of the globe; for it seems to be proved, that the same species is never common to two different orders, and rarely to two subformations even of the same group.

The shells of molluscous animals are more numerous than the remains of any other of the grand divisions of the animal kingdom; they have, therefore, hitherto furnished the most obvious distinction between the several formations. In the diluvium they differ from those of the present day, principally in furnishing evidence of the extension of such a climate, as we now find within the tropics, to the temperate zone. In the Pliocene, Miocene, and Eocene groups, they gradually change their character, until less than half the fossil shells of the latter belong to existing genera. In the higher formations of the supermedial order, an entire change in the fossil shells is observed, so that it would appear as if the deposit of the last layers of chalk was accompanied by the entire extinction of all the species, and most of the genera then living, which were succeeded by a new creation.

193. It is unnecessary to dwell longer on the detail of these changes in animal life; it is sufficient for our purpose to state, that in proceeding from the lower to the higher orders, there appears to have been a gradual development of the powers and functions of animal life; for, if the grand divisions whose organization is least perfect continue to exist up to the present day, although in new families, genera, and species; there are added to them at each successive step, families, orders, and grand divisions of more and more perfect organization, until the scale is terminated by man, superior in this respect to any other animal.

194. Similar evidence of frequent and successive changes in the state and climate of the surface of the globe, are to be found in the study of vegetable fossils. In the modern formations we find little to show that the flora, even of the diluvial period, was materially different from our own. But, even in the higher strata of the superior order, a marked change is to be detected, although not so much in the existing genera as in the places where they occur: thus, the fossil flora of the basins of London and Paris consists of palms, spice-bearing laurels, and other plants manifesting the existence, in those temperate latitudes, of a tropical climate. But if we consider these plants in reference to the grand divisions of the vegetable kingdom, the proportion among them is much the same as at present. The dicotyledons were then, as now, most numerous, and the cryptogamia the least so.

On passing into the formations of the supermedial order, this relation among the divisions of the vegetable kingdom changes. Dicotyledons disappear, and the cryptogamia exhibit themselves in greater abundance. One-third of the species belong to the single family of ferns, and, with the cycadæ and coniferæ, make up nearly the whole vegetation.

In the medial order, the vegetables are remarkable for the small variety which exists in their species, and for the greatness of their magnitude. All the vegetable fossils of this order are comprised in no more than six families, while those of the present day number 200. Of these six families, four belong to the cryptogamia, one to monocotyledons, and the sixth probably to dicotyledons, although it is so different from any of those of the present day as to leave a doubt as to its classification. These six families include 258 fossil species, in every hundred of which 92 are vascular cryptogamia; while at the present day, in every hundred species no more than four belong to that class.

Another important difference is to be found in the fact that these prevailing families, which at the present day are mere herbs, or rarely aspire to the size of shrubs, exist in the medial order of the most gigantic dimensions.

195. The study of the manner of formation of coal is intimately connected with the subject of vegetable remains.

Carbonaceous matter is not limited to the coal measures, but is found in every one of the orders of stratified rocks, as well as in the alluvium and diluvium.

(1.) Beds of turf form a part of alluvial formations, and are caused by the growth and death of vegetables, which still live and flourish in the immediate vicinity. These beds often contain fossil trees, in sufficient abundance to resemble prostrate forests. The wood of these is partially altered, the elements of the oleaginous and resinous parts having entered into a new combination, namely, bitumen.

(2.) Beds of turf are also covered and intermingled with diluvium. The turf of these has undergone a chemical change, and the imbedded trees have often passed into lignite or brown coal. The bed of brown coal at Bovey-Heathfield, is covered only by diluvium.

(3.) Lignite, jet, and amber occur in the formations of the superior order; the two latter are of a vegetable origin as unquestionable as the first.

(4.) Thin seams of brown coal, often retaining a distinct vegetable structure, occur in the chalk, but are more frequent in the green and iron sand. Similar seams are found in the oolitic group. In the triasic group true coal makes its first appearance, although in thin seams of no value for working.

(5.) The anthracite and bituminous coal of the coal measures, are often intermingled with fossil charcoal, retaining the ligneous structure. Vegetable impressions are abundant in the shales contiguous to the coal, and although the peculiar cubical fracture of bituminous coal, and the conchoidal fracture of anthracite mask the vegetable form, it is often possible to develop it by careful cleaving. Coal occasionally alternates with the carboniferous limestone, which also contains bitumen, and the carboniferous sandstone contains thin seams of coal.

(6.) The transition limestone is often completely impregnated with carbon and bitumen, and the slate of the submedial order contains anthracite imbedded, and also in thin seams.

(7.) The rocks of the inferior order contain plombago, and although all signs of vegetable structure have disappeared, analogy would lead us to ascribe that of the inferior slate, at least, to the same origin.

The changes which are observed in the fossil wood of the modern formations, and which differ only in degree in the lignites and brown coal of the superior and supermedial orders, show that it is only necessary for vegetable matter to be steeped for a sufficient length of time in water, to cause it to assume a bituminous character. In order to account for the formation of true coal and anthracite, it is necessary to call in the action of heat. This, if acting upon brown coal, subjected to pressure, will fuse it, and on cooling there is every probability that it would assume the form of bituminous coal. If the pressure be less intense, the volatile matter would escape, and anthracite would be the result. That the coal measures have been subjected to heat appears from the character of the rocks, whose argillaceous cement is indurated like baked clay, and the source of this heat is apparent in many coal formations, in the presence of trapp and porphyritic rocks, in dykes, and intercalated masses.

196. The universal prevalence of the formation we have called diluvium over the whole surface of the continents, shows that the present land, after having been raised from beneath the ocean, had been subjected to at least one return of its waters, which had risen high on the sides, if not to the tops, of the most lofty mountains. It is yet a question whether there had been one or more of these catastrophes. It is obvious, that if a deluge were to pass over the present surface, the loose diluvium and alluvium now existing would be mingled and confounded with the deposits of such a flood. There is one instance already known, in which a bed of diluvial gravel has been disturbed by a change in the form of the rocks beneath, and is covered in part by a similar bed of less thickness, which has not been disturbed. This is sufficient to show that two successive floods have prevailed in that place. A few more observations of the same nature, at remote distances, would prove that two deluges had occurred, instead of one.*

The large size of many of the diluvial boulders, as well as the abundance of the deposit in many places, shows that the action of the waters must have been intense; while the small degree of attrition which they have met with, shows that the catastrophe must have been of short duration.

The phenomena of erratic blocks have been plausibly accounted for, by supposing that the deluge, rising to the tops of lofty mountains, had floated thence the glaciers, with the masses of rock imbedded or adhering to them. These glaciers, grounding on the subsidence of the waters, and melting, may have left these blocks in the places they now occur. As the largest and best known blocks are derived from the Swiss and Norwegian Alps, this hypothesis is far from improbable.

197. The coal measures have unquestionably been depo-

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*This view of the subject is most consistent with the Mosaic record, which describes the earth at the time of the creation as covered with water, besides recording a subsequent deluge; and with the fact that by far the greater part of the remains of terrestrial animals, found in diluvium, belong to extinct species, would be reconciled with the record of the preservation of animals at the deluge of Noah.

sited in basins, forming the beds of fresh water lakes. The formations of the superior order are also of the basin form, and manifest the alternate prevalence of fresh and salt water. Neither of these, however, lie in the position in which they must have been at first deposited.

The occurrence of similar basins, in which all the sedimentary rocks have been deposited, is the only mode in which it appears possible to account for the limited extent of these several formations, and the fact that they often exclude the basins of more modern origin. It is therefore evident, that the relative levels of the surface of the land and ocean, must have been many times changed, between the time to which we can trace back the earliest geological formations, and the last great catastrophe.

That such changes of level have been of frequent occurrence, and are sufficient to account for these alternating influxes of the ocean is now demonstrated by the brilliant discovery made by de Beaumont, of a method of determining the geological age of mountains.

This method rests upon the simplest principles:

(1.) The ancient rocks of aqueous origin must have been originally deposited in layers, nearly horizontal. No other variation from this could have occurred, except in the greater thickness of the strata in the deeper parts of the basin in which the formation took place. If, then, we find such rocks, elevated to the tops of mountains, or lying on their sides in inclined positions, the inference is direct, that the mountains must have been raised since the rocks were deposited.

(2.) If, on examining the pebbles of gravel, or of conglomerate rocks, we find all the longer axes lying in a horizontal position, it is obvious that the bed has not been disturbed; but if any of the axes occur in inclined positions, a disturbance is to be inferred.

198. Applying these principles to the mountains of Europe, de Beaumont found:

That the central Alps, including St. Gothard, had been raised after a great part of the diluvium had been formed, while in the neighbourhood he found the indication we have referred to, of a posterior deluge;

That Mount Blanc and the Western Alps were raised after the deposit of the formations of the inferior order, but before the diluvium;

That the Pyrenees and Appenines were of an origin subsequent to the deposit of the chalk, and before the formations of the superior order.

Continuing this investigation he was led to the remarkable result, that the height and magnitude of mountains diminished as the date of their origin became more remote. He also inferred, that mountains of similar date were arranged in lines parallel to each other; and extending this to the case of mountains which he could not visit, he inferred that the Himmalaya was of the same date with the central Alps, and therefore subsequent to a part of the diluvium.

Reasoning in relation to the Andes, he infers, that this vast chain of mountains, composed principally of trachyte, and whose craters still vomit forth igneous matter, was the most recent of all those which we find on the surface of the globe.

He further found that the elevation of mountains had not taken place separately, or in a continuous manner; but that numbers had been raised at or about the same period, and the convulsion which gave them birth had been succeeded by long intervals of repose.

Thirteen such convulsions, including that which he supposes to have given birth to the Andes, were noted by him; the oldest of these only goes back to the epoch of the formation of the carboniferous groups.

Applying these principles to the mountains of the United States, it may be inferred:

That the lower ramifications of the Atlantic chain, from the island of New-York to Georgia, were raised at a date anterior to the deposit of any sedimentary rocks;

That the Atlantic ridge itself is posterior to the transition limestone, and probably to the red sandstone of New-Jersey, which is much disturbed in its neighbourhood;

That the other ridges of the Apalachian group are subsequent to the coal measures.

199. We have used the term elevation in speaking of the origin of mountains. It is however obvious, that the appearances they present may have arisen as well: from the falling in of the adjacent strata; from the formation of great faults, in the strata of which they are themselves composed; by the twisting and bending of their own strata, in consequence of a contraction of the dimensions of the globe, as from the protrusion of an igneous rock, through a level part of the crust of the earth. In examining mountains, all these different methods of formation are distinctly visible, and, in addition, some ridges of no great elevation are wholly composed of overlying masses.

200. In examining this theory in connection with the facts, it appears: that the greatest range of mountains on the surface of the globe, is of the most recent origin, and that its elevation has been followed by a period of repose probably longer than any which preceded it; that, as we proceed back in the earth's geological history, the convulsions appear to diminish in extent, while the periods of their recurrence become more and more frequent. As we have no right to conclude that the revolutions of the globe are at an end, it is to be inferred, that the present quiescent state is to be terminated by a convulsion of still greater violence, and which may cover the whole existing face of the continents

with one igneous flood. Such is the close of the existing state of things predicted in Scripture, and rendered probable by the analogy of geological phenomena.

201. It is to be inferred, that the phenomena of the elevation of mountain ridges, accompanied and preceded as they must have been by earthquakes, would have produced a violent action in the waters of the ocean. In the much less violent commotions which are still occasionally witnessed, great waves are raised, which are thrown with violence over the shore. Of this we have instances, among others, in the destruction of Port Royal and Callao. If such phenomena accompany partial earthquakes, which find vent in the feeble eruptions of modern volcanoes, we may conceive how great must have been the commotion when such ranges of mountains as the Alps, the Himmalaya, and Andes, rose from the depths of the ocean. In conformity with this view of the subject, we find that the geological epochs of the formations of the triasic and carboniferous sandstone and conglomerates, indicating a violent action of water, were those of the elevation of numerous mountain chains; that these, although numerous and frequent, being of small extent, the formations do not occupy a great portion of the earth's surface; that the elevation of the Alps and Himmalaya seems to have been attended with an universal deluge, which in all probability immediately preceded the Mosaic epoch of the creation of man. Pursuing the same view of the subject, it may be inferred: that the elevation of the Andes presents a physical cause sufficient to account for the deluge of Noah, which, however violent upon the new continent, must, upon the old, at such a distance from the source of the catastrophe, have been slow and gradual in its rise.

202. It remains to inquire into the physical causes of the heat, which has played so prominent a part in the changes which the earth's surface has undergone. The law of spe-

cific heat shows us that, whenever a body is compressed, its temperature is raised; and as the bodies which compose the interior of the earth are compressed by those which lie between them and the surface, we have a general law which is sufficient to account for the regular increase of temperature which is found in descending into mines. We may next infer by calculation, that at a depth of from 20 to 30 miles, the heat growing out of mere pressure, will be sufficient to fuse all matters of the same nature as those we find at the surface of the earth. Now, as there is no reason to suppose that the interior is composed of elements different from those which exist at the surface, the inference is immediate that the interior of the earth is in a state of igneous fusion.

In going a step further back, the same law of specific heat will show us: that when the matter which now composes the earth was first brought together, it must, unless the present laws of nature had not begun to act, or had been suspended for the occasion, have been in a state of intense heat, growing out of the mere condensation into a limited space of so great a quantity of matter. The igneous fusion, then, instead of being confined to the surface alone, must have prevailed throughout the mass, which, existing in a liquid state, would have assumed the very figure which observation shows us the earth at present has.

A globe thus intensely heated, and situated in a space colder than itself, will part with heat by radiation, and were this the original state of the earth, it would have cooled, with a rapidity having relation to the heat of the surface, until the quantity of heat radiated, and of that received from the sun, should exactly balance each other.

This state of calorific equilibrium, the earth, as we learn from an argument founded on astronomic phenomena, has nearly, if not completely, reached. At any rate, the mean temperature of the globe has not, for 2000 years, varied more than one-tenth of a degree of Fahrenheit's thermometer. It has however been maintained, that the phenomena of volcanic action are due to a shrinking in the crust of the earth, growing out of a diminishing temperature, and the whole quantity ejected by all the active volcanoes is not sufficient to contradict the preceding statement, that the temperature of the earth is now nearly constant.

203. As the proposition that the original state of the earth was that of igneous fusion is founded upon a well-known and universal physical law, it might, consistently with the strictest rules of inductive reasoning, be made the foundation of a theory. Were we to pursue this, we should find it capable of explaining innumerable geological phenomena.

FINIS.

CORRIGENDA.

Page 6, line 24, for "decrease" read "increase."
" 55, line 16, for "form" read "fern."
" 55, line 5 from bottom, for "surrounding" read "succeeding."
" 57, line 19, after the word "trilobites" insert "in the carboniferous."
" 74, line 19, for "masses" read "mines."

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